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SEA JAVELIN: AN ANALYSIS OF NAVAL FORCE PROTECTION ALTERNATIVES

by

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13. ABSTRACT

The US Navy continues to provide a forward presence, conduct freedom of navigation operations and deploy in areas around the world. There exists a very real threat to the vessels and crew of the US Navy; terrorists have proven that they are willing and able to use low-cost, high-impact weapons. The US Navy needs weapons that are mobile, cost-efficient, easily integrated into the fleet and, most importantly, these weapons are needed immediately. This need, combined with current budgetary considerations, compels us to seek weapons that are ready to be employed into the fleet today. The traditional evolutionary process will not provide a capable weapon in a timely or cost-effective manner. The need, as does the weapon to meet that need, exists today. That weapon is the Army M98A1 Javelin Anti-Armor Missile.

The goals of this thesis are to:

(1) Examine the need for a stand-alone, point-defense weapon for use on surface vessels to effectively combat the small boat threat while underway in restricted waters as well as in port.

(2) Discuss the shortfalls of current weapons systems used in the fleet to combat this threat.

(3) Identify the suitability of the Javelin to meet that threat.

(4) Discuss the potential and substantial cost savings available to both the United States Navy and Army if such an endeavor were to take place.

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SEA JAVELIN: AN ANALYSIS OF NAVAL FORCE PROTECTION ALTERNATIVES

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ABSTRACT

The US Navy continues to provide a forward presence, conduct freedom of navigation operations and deploy throughout the world. There exists a very real threat to the vessels and crew of the US Navy; terrorists have proven they are willing and able to use low-cost, high-impact weapons. The Navy needs weapons that are mobile, cost-efficient, easily integrated into the fleet and, most importantly, these weapons are needed immediately. This need, combined with current budgetary considerations, compels us to seek weapons that are ready to be employed into the fleet today. The traditional evolutionary process will not provide a capable weapon in a timely or cost-effective manner. The need and the weapon exist today. That weapon is the Army M98A1 Javelin Anti-Armor Missile.

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I.INTRODUCTION

A. PURPOSE

The purpose of this paper will be to examine the need for a stand-alone, point-defense weapon for use on surface vessels to effectively combat the small boat threat while both underway in restricted waters where traditional organic weapons would prove ineffective or difficult to utilize as well as while in port where organic weapons systems are traditionally powered down or in an otherwise unusable state. This paper will provide a realistic analysis of the current self-defense capabilities of US Navy ships against this type of threat. It will provide a viable argument that there is in fact a need for a short-range weapon system capable of being employed while in port or when transiting through restricted waters. This paper will analyze and evaluate the constraints placed on the use of radar systems and their related weapons while in port or within a specified number of miles from land. This paper will address the current threat to surface ships vis-à-vis the October 12, 2000 terrorist attack upon the USS Cole in Yemen and a recent analysis by the UK Royal Navy (RN).

Furthermore, this paper will analyze the potential suitability and effectiveness of the US Army Javelin missile to meet this asymmetric threat. This paper will attempt to address the lack of suitability of current weapon systems to combat this threat in terms of accuracy, effectiveness (lethality) and relative cost-per-kill.

Finally, this paper will analyze the cost that the US Army has invested in its acquisition of the Javelin

missile. The goal will be to illustrate how both the US Navy and Army could benefit from a strategic financial partnership with respect to the continued funding and fielding of the Javelin missile. In short, the intent of this thesis is to identify areas where US DoD can realize a tremendous cost savings while attaining a substantially improved self-defense capability against this asymmetric threat with minimal financial impact.

B. BACKGROUND

The Royal Navy is currently undertaking plans to improve its anti-surface warfare (AsuW) capabilities. The focus of these plans will be protection against "asymmetric" surface threats operating in the littoral regions. The UK Ministry of Defence's Directorate Equipment Capability (Above Water Battlespace)- DEC (AWB) have determined that there is a potentially dangerous gap in the ability of its ships to defend themselves against fast attack craft (FAC) and fast inshore attack craft (FIAC's). They have decided to make this a priority in their force upgrades plan.

FAC's are small combatants that are equipped with surface-to-surface guided weapons and FIAC's are classified as small fast craft such as powerboats, interceptors, rigid inflatables and even jet skis. These FIAC's can be equipped with a range of short range weapons that include short range missiles, rockets, rocket-propelled grenades (RPG's), heavy machine guns or as suicide vessels laden with high explosives.

Attacking in "swarms", these vessels generally lack the ability to sink a ship but the attacks would at least

interfere with the ship completing its primary mission. However, it would not be impossible for one of these attacks to result in significant damage to a ship's systems and sensors and effectively disabling a warship. [Ref.1] The US Navy, as it operates in almost all areas of the world is susceptible to the very same threats identified by the Royal Navy.

In addition to the direct and coordinated "swarm" attacks from organized enemies there exists an even more asymmetric threat, the terrorist suicide bomber. The effectiveness of this method was evidenced on October 12, 2000 in Yemen. The Arleigh Burke destroyer, *USS Cole* despite being equipped with the sophisticated Aegis radar systems and being one of the most capable warships in the world, was quite literally crippled and 17 of her crew were killed by two men and a bomb in a small boat. A vessel like the Cole was designed to protect a carrier battle group and engage in major air, sea and submerged threats in a large-scale sea battle.

This one billion dollar warship was equipped with missiles, guns, radars, countermeasure devices, "Phalanx Gatling guns", helicopters and even torpedoes. Despite all the armament and technology, protection against terrorist attacks is limited to the on-board security personnel armed with only small arms and fire hoses. [Ref. 2] Some may argue that the attack on the *Cole* was only successful due to the lack of response by the Captain and crew of the Cole. This is not the crux of the issue, but it is used simply to illustrate the following two points. Firstly, a small suicide boat threat does in fact exist. The second

point at issue is the fact that the principle means of defense against a threat of this type, in a situation such as this, is the arsenal of small arms on board the ships.

C. RESEARCH QUESTIONS

This thesis will determine whether the small boat threat is a real one. This thesis will, to a lesser degree, show that the threat which the organic weapon systems on the ships were designed counter are unlikely to be used by our present-day adversaries. Beyond the design limitations of these weapons, due to their minimum range and automaticity; there is a significant danger of fratricide due to their maximum ranges. This thesis will show that the small arms presently used for ship's self-defense are inadequate in both their accuracy and lethality.

It will also argue the fact that there is a need for a cost efficient, accurate point-defense weapon that can be easily integrated into the fleet in a cost-effective manner

This thesis will also show that the US Army Javelin is a perfectly suited weapon to meet that need in all respects.

Finally, this thesis will attempt to quantify the potential cost savings that could be realized through the use of an already proven and existing weapons system. "The acquisition of new weapon systems is a long and expensive process. Research, Test, Development and Evaluation (RDT&E) is a critical, timely and costly step in that process." [Ref. 1] As the US Navy continues to fill its role in the pursuit of world peace through power projection and forward presence, our ships must be given the tools

with which to defend themselves. These tools must be capable, cost-effective and most importantly; they must be timely.

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II. CURRENT THREATS

A. INTRODUCTION

The current threats, when combined with the necessarily restrictive rules of engagement (ROE) result in very short reaction times for self-protection. This is the case for both the FIAC and the suicide boat attack scenarios. This chapter will address both scenarios and the need for a significant added layer of defense. In the case of the FIAC's there are several factors that make it a difficult tactic for ships to defend themselves against.

It may be argued that there is little or no defense against an attacker who is willing to sacrifice his or her life for the lives of many victims; as was the case in the Cole attack. While the argument may be taken to its logical conclusion, that in the future a small boat would not be allowed to approach as closely as the boat in Yemen. This only adds to the case for the need of a weapon that has the stopping power to quickly and efficiently destroy such an attacker once identified.

The following sections will address the current composition of ship's self-defense weapons, the status of these weapons systems while transiting in and out of port as well as when they are along side the pier and their limitations against this type of attack while configured as such. The author will also review the potential composition and tactics that attackers might use. Finally, this section will give an economic evaluation of the threat and its appeal to terrorist and countries or organizations that do not maintain a "traditional" blue water navy.

B. CURRENT VULNERABILITIES/SHORTFALLS IN SELF-DEFENSE

In the previous section there were two situations referenced that placed US Naval ships in a less than optimal position for self-defense against the small boat threat. Both circumstances will be used to illustrate the shortfalls in the defensive postures of these vessels. While US Navy ships are entering or leaving a port and particularly when they are moored along side a pier, they are especially vulnerable to a suicide boat attack. In the former they are severely limited in their ability to maneuver due to the usually narrow channels they must transit through and in the latter they are not maneuverable at all.

In addition to the vessel's lack of maneuverability in both cases, there is the dilemma of how best to employ the limited number of ship's force personnel while transiting a narrow channel. All visual and radar navigation stations are manned. All redundant ship steerage stations not normally manned are. Additional lookouts are posted with communications to the bridge either directly or indirectly. A high percentage of the crew is topside handling or preparing to handle lines. On the positive side, there is a heightened state of damage control preparedness due to the fact that all doors below main deck are made watertight and personnel are manning extra watch stations.

In short, during what is called "restricted maneuvering", a situation where almost all other concerns are secondary to the safe navigation of the ship, there is a shortage of personnel to protect the ship against a

suicide boat attack. “Today, when their enemy is unlikely to come at them with jets or submarines, when a fishing vessel could be a floating bomb, they (ship’s crew) must peer at every blip on their consoles.” [Ref. 4] When ships are transiting through narrow channels there are sometimes literally hundreds of small contacts, each of which has the potential to be an attacker.

While along a pier, ships are even in less of a position to protect themselves effectively. With sometimes as little as one-tenth of the crew on board, there is a shortage of personnel to provide an adequate topside presence. As ships struggle to balance quality of life for its crew when in port against safety of the ship, the latter usually suffers. Even when in a heightened state of readiness the ship’s force is limited in its arsenal of weapons available to defend against an attack. Organic weapons systems are powered down for maintenance or safety. Even if these systems were powered up they would be ineffective due to their minimum ranges and the fact that the use of radars (which is used for targeting) is prohibited while in port. Ship’s self-defense forces are limited to the use of 9 MM and 45 caliber handguns, M-14 or M-16 rifles and in extreme cases, 50 caliber M-60 machine guns.

There has been an increasing number of littoral campaigns in the recent years, operations in these confined coastal areas has changed both the significance as well as the nature of naval threats. In these cases small fast craft, patrol boats and “rigid raiders” have the capability to sneak by radar coverage and come within close range (5

km) before they can be detected. [Ref. 5] The "small boat" scenario is a very real one, simply because, you can hide small boats.

The bottom line is that the US Navy needs to prepare itself for the changing face of naval warfare; it needs to prepare to do battle in what is now known as "brown water". These brown water engagements are those that take place in the enclosed waters near hostile shores. A perfect example of this is the Persian Gulf region; there are numerous land bases from which small attack boats may come. The threat will not come in the form of large and coordinated attacks but rather, they have the potential to come in the form of a surprise or even a disguised attack.

How effective would the weapons of a naval vessel that were originally designed to combat a large full-scale naval or air battle against other surface combatants be? These vessels have numerous defenses against the large mass air raids from enemies such as the former Soviet Union and even the Anti-ship cruise missiles (ASCM's) from small and fast missile boats that are commonly found in almost all the navies of the world. As effective as these weapons may be against the threats and tactics described above, they are limited in their usefulness against a dozen small, fast and maneuverable explosive-laden suicide boats.

In the best-case scenarios heavily armed combatant warships would, at the very least, suffer some level of degradation in their primary mission areas. In the worst-case scenarios non-combatant warships such as oilers and re-supply ships, mine counter-measure ships, command and control ships and even hospital ships would suffer much

worse from these attacks. There is another class of ships, the amphibious assault ships, which fall into a category somewhere between these in both armament and vulnerability. The most vulnerable craft are surfaced submarines; these vessels have only small arms to defend themselves in these situations.

C. ECONOMIC EVALUATION OF THREAT

"The United States is an unrivaled military superpower, with its precision guided weapons, well-trained troops and global reach. So instead of fighting the Pentagon on its own terms, the nation's (US's) enemies have been looking for its Achille's heal." [Ref. 6] This "Achille's heel" is apparently taken advantage of in the form of "asymmetric warfare." This has been described by military theorists as "the use of unconventional tactics to counter the overwhelming conventional military superiority of an adversary." The author goes on to say that: "The US has an overwhelming technological superiority over the conventional military forces of virtually any conceivable adversary, but remains vulnerable to certain types of unconventional response: terrorist attacks, weapons of mass destruction, or unpredictable actions in unpredictable places, like the attack on the Cole in Aden." [Ref. 7]

In the end, asymmetric warfare means that someone isn't playing fairly. They are using tactics that haven't been "agreed to." As we look at the significant economic and military advantage the United States has when compared to the resources of its adversaries, it is understandable why this path has been chosen. What our enemies are looking

for is two-fold. They are looking to take advantage of our weaknesses and they want to do it cost-effectively. The former has been illustrated above, and the latter will be illustrated in the following paragraphs. With respect to their cost-effectiveness or, "bang for the buck", the suicide boat more than pays for itself in results. "The suicide boat attack is a poor man's guided weapon. Clearly it is tremendously effective. The attack killed five (later determined to be seventeen) Americans and disabled a billion-dollar US warship." [Ref. 2]

In the case of the attack on the Cole, the exchange was very favorable on the side of the terrorists. The cost of repairs for the Cole totaled $240 million. [Ref. 8] The costs were not just monetary; 17 crewmembers were killed and 37 were injured in the blast, which tore a hole in the ship's side. In addition to the cost in terms of lives and money, a new warship was taken out of operation for 18 months. The cost to the terrorist was minimal in comparison, 400-700 pounds of C-4 military style plastic explosives that may or may not have cost them anything [Ref. 9], the lives of two willing extremists, a small rubber boat and some time.

There is little doubt that the highly sophisticated and expensive warships of the US Navy present very attractive targets to terrorists. The tactics used are low-cost and have a very high impact on our forward deployed forces. It is a matter of fact that similar attacks will be attempted against our forces here in the United States. As ships transit in and out of harbors like Norfolk and San Diego (two largest naval bases) they would be extremely

vulnerable to an attack from a handful of suicide boats such as Boston Whalers or powered fishing boats. This scenario, when applied to ships entering ports like Hong Kong or Singapore where the number of boats in the harbor increases exponentially, illustrates that there is indeed a significant threat.

Although there have been no attacks on US ships in those regions, there have been attacks that fit this profile. In September of 2001 a group calling themselves the “Tamil Sea Tigers” attempted a suicide attack against a merchant ship transporting about 1,200 government soldiers to the Jaffna peninsula. In this attack approximately 20 explosive-laden boats with “suicide cadres” on board attacked the *Pride of the South*. The soldiers on board fired on the boats and destroyed two of them; one of the Sri Lankan patrol craft was damaged by a suicide boat and was towed back to port. This attack was the second such attack in 24-hours by the rebel naval wing of the Tamil Tigers. Another attack damaged a military craft when a suicide boat exploded at the mouth of the eastern port of Trincomalee.

The tactic of using explosive-laden suicide boats to ram and sink military vessels is being used quite regularly in Sri Lanka’s northern and eastern regions. The attacks were proven to be effective when on 24 July of the same year the “Tigers” devastated the country’s only international airport in a land-based version of these suicide attacks by destroying a dozen commercial and military aircraft. [Ref. 10]

Other examples of the potential use of these tactics include the 23 October, 2002 attack on a Greek warship

operating near the entrance to the Persian Gulf. A small, high-speed boat approached the Greek ship. The ship fired warning shots and the boat turned away. A nearby group of Japanese support ships was warned and placed on alert, fearing the incident indicated another al Qaeda attempt to attack ships from nations supporting the war on terror. Also, Yemen has admitted that the recent explosion and fire aboard a 300,000-ton French oil tanker Limburg was the result of a 6 October, 2002 terrorist attack. The tanker had slowed to pick up a pilot for entry to Yemen's oil loading facility. A small boat approached and there was an explosion when the boat appeared to hit the Limburg.

Again, the use of suicide boat attacks using conventional explosives is not a new tactic. In May of 1964, the *USNS Canard* (World War II escort carrier) was sunk by VC terrorists as it sat dockside in Saigon Harbor. Military Sea Lift Command had used the *Canard* for troop and aircraft transport. [Ref 11] Conventional bombs have been the weapon of choice for terrorists throughout the years. Their repertoire includes shootings, bombings and assassinations. Prior to the recent combined attack on the World Trade Centers and the Pentagon (which it could be argued also falls into the category of a suicide bombing), the majority of US personnel killed by terrorists have been from bombings [Ref. 11](see figure 1 below).

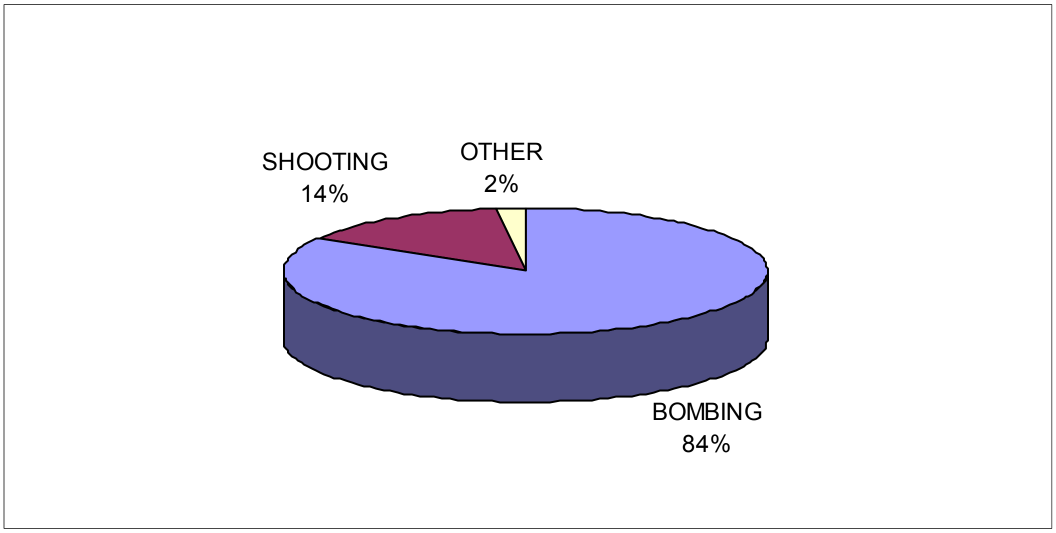

Figure 1: DoD Deaths by Type of Attack (1947-2000) [After Ref. 11]

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III. ANALYSIS OF CURRENT WEAPONS SYSTEMS ON US SHIPS

A. INTRODUCTION

US Navy ships use what is called a “layered defense” in the employment of their weapons for self-defense. This term is generally associated with air defense and usually includes the use of inorganic assets such as satellite imagery and carrier-based aircraft. This terminology can logically be applied to the manner in which US Navy ships defend themselves against surface vessels.

For the purpose of this thesis the author will assume that we are discussing only organic (shipboard) weapons systems. This is not done as a matter of convenience; rather this is done as a matter of reality. The situations when there are inorganic assets available for protection against surface vessels occur generally when ships are conducting open ocean operations far away enough away from land so that the type of threat we are discussing literally does not exist.

The organic weapons that US Navy ships have at their disposal for use against a small surface vessel include the following:

1) SH-60B Helicopter (Penguin Missiles)
2) Tomahawk Anti-Ship Missile (TASM)
3) Harpoon Anti-Ship Cruise Missile (ASCM)
4) Standard Missile (SM-1 & 2) in “Surface Mode”
5) Rolling Airframe Missile (RAM)
6) NATO Sea Sparrow Missile (NSSM)
7) 5-inch Gun

8) 76 MM/ 3- inch Gun
9) Close-In Weapons System-1B (CIWS-1B)
10) 25 MM Bushmaster Chaingun
11) M-60 Machine Gun/ .50 Cal
12) Small arms (9 MM, Shotgun, 45 Cal, M-14, M-16)

While the preceding list seems to provide a formidable arsenal for the ship to draw upon for self-defense, there are several reasons that there is still a need for a more effective weapon system. All of these weapons are not available on all ships and most of these weapons are not suitable for the threat being discussed. With respect to suitability, the following criteria have been established to define what that entails. The weapon must be feasible to use, have a relatively low cost-per-kill and perhaps most importantly, it must be effective in combat.

"Feasibility of use" implies that it is a weapon that the Commanding Officer (CO) of a ship would be willing to or able to use if the situation warranted it. For example, how willing would the CO of ship pulling into San Diego harbor be willing to have the CIWS mounts or the deck guns rotating and pointing at every small craft that was floating past them? Would he or she be willing to authorize the release of a weapon that could easily travel beyond the horizon? The second aspect of "feasibility" is whether or not they could be used at all. If a ship were sitting next to a pier, given the current restrictions on transmitting radar while in port, both of the previously mentioned weapons would be incapable of being employed at

all. Or more than likely in the case of a missile, is the target inside our minimum engagement envelope?

"Relative cost-per-kill" refers to the cost per successful engagement (assuming that the target is destroyed or neutralized with the minimum designed salvo size). In the case of a missile engagement, the actual cost of the missile would be the cost-per-kill (assuming target destruction or neutralization with one missile). While it could be argued that the dollar value would be insignificant if a potential attacker were killed, it still requires some consideration. If for no other reason, one must take into consideration the fact that there will be both training and qualification expenses associated with each weapons system considered.

Finally, third in the list of criteria to be considered (and perhaps the first in importance) would have to be combat effectiveness or the likelihood of success in destroying an attacker. Just how effective is an eighteen or nineteen-year-old sailor shooting an M-14 or M-16 at a small moving target in the dark? How effective is a 5-inch gun against a high speed, maneuvering target?

B. MISSILES

1. Penguin Missile

As we work our way from the outside of the engagement envelope to the inner portion we first look at the missile defense systems available for ship's self-defense. The first "layer" would be the SH-60B helicopter that is employed only on Cruisers, Spruance Destroyers, Flight IIA

Arleigh Burke Destroyers and Frigates. The primary mission of these helicopters is that of Anti-Submarine Warfare (ASW). Some of these helicopters are equipped to employ the Mk 2 Mod 7 "Penguin" missile. SH-60B's equipped with the missile can be used in the additional role of Anti-surface warfare (ASUW) attack.

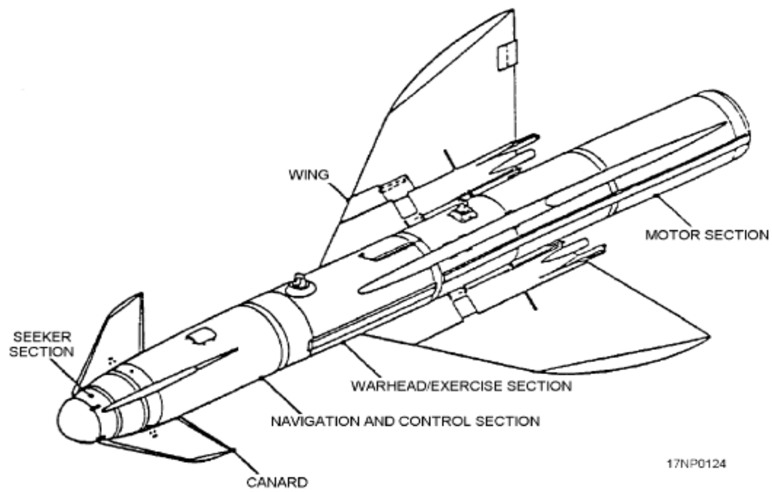

Figure 2: AGM-119B Penguin Anti-Ship Missile [From Ref. 12]

Besides the fact that not all ships have this asset available, the shortcoming of this helicopter-launched missile in this warfare area is three-fold. First, in the coastal or littoral environment these helicopters can easily fall within the engagement envelopes of a variety of surface-to-air missiles from shore. Secondly, to use a helicopter in an ASUW role such as this, there would have to be some type of warning that an attack was imminent or at least probable. Finally, in the case of the narrow channel transit in and out of a busy port, it would be dangerous to attempt to employ a weapon such as the Penguin missile. The missile has a 120 kg warhead and is designed to inflict serious damage to a medium-sized surface

combatant. The size of the warhead, its 25 nautical mile range and the fact that the potential target would be in close proximity to the ship being defended would make it difficult if not impossible to employ the weapon with any confidence. [Ref. 12]

2. Tomahawk Anti-Ship Missile

The next missile in the arsenal would be the Tomahawk Anti-Ship Missile or "TASM". The US Navy originally developed the Tomahawk missile as the TLAM-N (Land Attack Missile-Nuclear strike variant) with TLAM conventional and TASM anti-ship variants following later. The TASM has a very real problem at both the lower and extreme end of its range envelope. The TASM has an operating range of 250 nautical miles and a maximum range of 470 nautical miles. [Ref.13] In addition to this impressive maximum range the issue of TASM's minimum range (classified) is such that it would make TASM virtually useless in an environment such as the one addressed in this thesis.

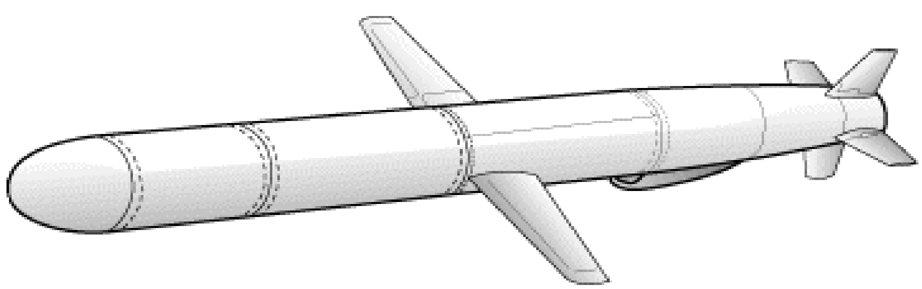

Figure 3: BGM-109 Tomahawk Anti-Ship Missile [From Ref. 16]

Beyond the range limitations mentioned above, the firing weight of a Tomahawk missile is 2,650 pounds; add to that a 550-pound booster and an average unit cost of $1,400,000 and you have a very large and very expensive weapons system. [Ref. 14] These specifications force the TASM to fail in both the relative cost-per-kill and feasibility of use criteria. Even if this weapon was useful in terms of feasibility of use, there is yet another problem. As the targets that absolutely needed such a large warhead were pretty much gone, the TASM has been withdrawn from service. After the fall of the Soviet Union, the ships that the TASM was designed to kill, cruisers of 6,000 tons and up, pretty much disappeared. Those TASM's that are left in the inventory are being converted to Block III TLAM's. [Ref. 15]

3. HARPOON Anti-Ship Cruise Missile

Next in our missile arsenal is the HARPOON Anti-Ship Cruise Missile (ASCM). The HARPOON missile was designed to sink warships in an open-ocean environment. Other weapons (such as the Standard Missile and Tomahawk missiles) can be used against ships, but the HARPOON and the previously mentioned Penguin are the only missiles used by the United States military with anti-ship warfare (ASUW) as their primary mission area.

Despite a sophisticated guidance system, the HARPOON cannot pick a hostile contact from a group of contacts particularly if the contact is a small gunboat. [Ref. 17]

The design aspects and capabilities of the HARPOON missile are indeed impressive. The factors that make this weapon system such an ideal and capable weapon for open-ocean warfare against moderate to large sized ships are exactly the ones that make the missile grossly inappropriate for close-in defense against a small surface target. By definition, the AGM-84D HARPOON is an "all-weather, over-the-horizon, anti-ship missile system" with a penetration 488-pound high explosive warhead (total weight of 1,145 pounds) and a unit cost of $720,000 [Ref. 18]. These high cost factors, combined with nearly the same low-end envelope limitations as the "TASM" and a similar high-end envelope issues, make the HARPOON missile fail the same criteria as the TASM and for the same reasons.

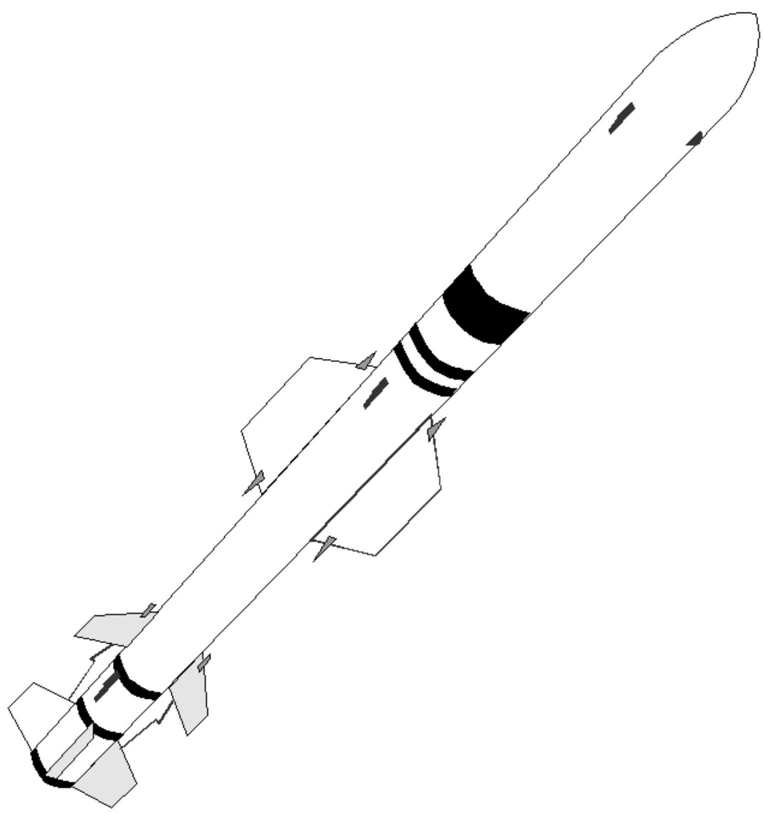

Figure 4: AGM-84D HARPOON Anti-Ship Missile [From Ref. 19]

4. Rolling Airframe Missile (RAM)

The Rolling Airframe Missile (RAM) is the primary weapon for self-defense on many non-Aegis US Navy ships. As of March 2000, the RAM Block 1 system has been installed on two LSD class ships, pending installation on two more LSD 41 class ships, LHD 7 and CVN 76. Plans call for the installation or upgrade of the Block 1 systems on 8 LSD 41/49 class ships, 3 DD 963, 12 XCV/CVN ships, 7 LHD and LPD 17 (new construction) ships between 2001 and 2006. [Ref. 20] In short, the US Navy has invested a significant amount of money to give ships the ability to protect themselves.

RAM was designed to be an effective, low cost, lightweight quick-reaction, self-defense system that increases the survivability of ships that were otherwise undefended. It is a 5-inch missile that utilizes SIDEWINDER missile technology for the warhead and rocket motor, and the STINGER missile's infrared seeker. RAM Block 1 upgrade has a limited capability against helicopter, aircraft, and surface (HAS) targets. This HAS improvement (in the form of a software upgrade) is currently being developed and is expected to undergo operational testing in FY 03. Concurrent with this design effort, an 11-round launcher system is also being developed for smaller ships and other vessels that have weight constraints. [Ref. 20]

Figure 5: RIM-116A Rolling Airframe Missile [From Ref. 20]

The RAM has a unit cost of $444,000 (Block 1), and carries a 25-pound warhead; it has an IR and RF-seeking warhead, a launch weight of 162 pounds and a range of approximately 11 miles. The US Navy is considering installing the 11-round launcher on CG 52 through CG 73 between 2004 and 2009 as well. All of this capability is contained in one of two launching vehicles (21-round or 11-round launcher).

At first glance the weapon system seems to be both a very affordable and very effective weapon. The system apparently meets two of the three criteria readily. It is in the feasibility of use that we find the weakness of the RAM in this threat area. To a lesser degree, there are also issues with its effectiveness.

Feasibility of use, assuming that a ship that has this weapon system (non-Aegis) is transiting into or out of a

busy and friendly harbor, how likely is the CO to have the system activated, with the launcher rotating and changing elevations as it targets any number of vessels? Even if a CO had indications and or warnings that an attack was possible, there would come a point that the maximum 11-mile range would become a limiting factor.

Another issue is the fact that the weapon uses combined infrared and radio frequency energy for targeting. A small boat attacking a ship with the intent being to ram it and detonate an explosive charge would not likely have any type of active transmitters onboard- this targeting method is a carryover from the weapon system's purpose of anti-ship missile defense. Secondly, there is still the lack of 360-degree coverage for the ship in question. The most significant shortcoming is the fact that this weapon becomes useless once along side the pier. It is unlikely that a base commander or CO of a ship would encourage or allow a weapon system with an eleven mile range to be powered up and ready to go pier-side.

While this weapon does provide a much-needed point-defense against anti-ship cruise missiles it is not the best weapon to use against this type of threat.

5. NATO & Evolved Sea Sparrow Missile

The NATO Sea Sparrow Missile (NSSM) is also a primary self-defense weapon used on many US Navy ships. The missile is classified as a radar-guided, air-to-air missile with a high explosive warhead. It has a cylindrical body with four wings at mid-body and four tail fins. The Navy

uses the missile primarily for surface-to-air anti-missile defense. The missile has a launch weight of 500 pounds and a maximum range of anywhere between 6 and 30 nautical miles (depending on which source is referenced) and a minimum range of approximately 1,600 yards. It has a 90-pound annular blast fragmentation warhead (35 pounds of which is explosive). The missile can be ordered from off to standby in 180 seconds and be ready to launch 2.3 seconds later. Maximum missile altitude is 25,000 feet. The warhead is both proximity and contact fused. It produces a continuously expanding rod 27-foot kill radius. The current unit cost for this missile is $165,400. [Ref. 21]

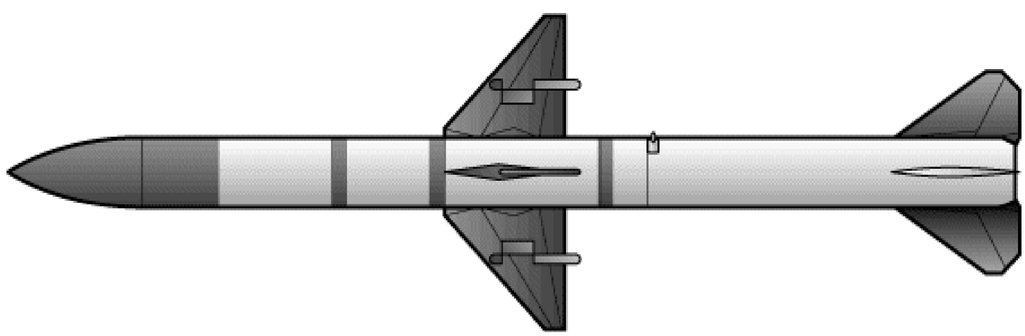

Figure 6: RIM-7 Sea Sparrow Missile [From Ref. 21]

There is an enhanced or "evolved" version coming to the fleet this year known as the "Evolved Sea Sparrow Missile" or "ESSM". Again, this is still classified as a short-range missile intended to provide self-protection for surface ships against anti-ship cruise missiles. It will be more capable against low observable highly maneuverable missiles, have longer range, and can make flight corrections via radar and midcourse uplinks.

On Aegis ships, ESSM will be launched from the MK 41 Vertical Launch System (quad-pack), requiring some modifications to the missiles themselves. On non-Aegis ships (aircraft carriers, amphibious assault ships, other surface combatants), it will be fired from a variety of launch systems. ESSM uses an 8 inch diameter body that includes an additional modified guidance section than the currently in-service RIM-7P Sea Sparrow. [Ref. 21] The final phase of the ESSM's flight test program is scheduled for early spring 2003, when performance with the AEGIS Fire Control System of the U.S. Navy's Arleigh Burke-class guided missile destroyers will be verified. [Ref. 22] Again, the focus continues to be on Anti-ship Cruise Missile defense.

Both the NSSM and the ESSM are primarily designed as a point-defense to combat the air threat. The use of either weapon against a speedboat or suicide boat attack threat is limited at best. NSSM, the current version, is currently the primary missile defense weapon on aircraft carriers, large deck amphibious assault ships, frigates and some other vessels. The ESSM upgrade will allow the use of these missiles on VLS ships as well (CG's and DDG's).

Firstly, with respect to cost-per-kill of these weapons, they do seem to be a relatively inexpensive weapon to use ($165,000 per round). With respect to the weapon's combat effectiveness; these weapons systems, as stated above, were originally designed to combat an air threat. As a result of this, their use in an ASUW mode is somewhat limited. There have been tests and evaluations that showed limited success in this mission area. Some of the limitations in

this area include the minimum range of 1,600 meters, launcher cutouts and their substantial maximum effective range.

With a minimum range of 1,600 meters, their use in combating an attack from a small boat threat is lacking. The decision to fire the missile against a potential attacker would have to be made once the target is no less than a mile away. Given the current rules of engagement and the prerequisite for a positive visual identification of the target as a threat, this would be a serious performance detractor.

The cutouts of the NSSM launchers in use today would mean that there would definitely be approaches that a small boat could take that would make it impossible for the NSSM to engage. The Vertical Launching Systems (VLS) that will launch the ESSM will necessarily increase the minimum range, as the missile will have to clear the launching vessel by some distance prior to beginning its "tip-over" towards the direction of the threat.

Finally, in looking at the issue of feasibility of use-we first must look at maximum range considerations. If we use the most common maximum effective range advertised (10 nm) we see that the possibility exists for this weapon to miss its target and continue on and detonate its warhead where it might harm friendly or neutral traffic, especially in a crowded harbor environment.

The next issue of feasibility of use takes into consideration the fact that you would be looking at a missile launcher training and elevating as a ship transits through narrow channels. This is a situation that the CO

of a ship would, at the very least, be uncomfortable with. Once the ship is tied up next to a pier this weapon system, as were the others discussed, is rendered totally useless. The requirements from ship's power, targeting data from a radar system and extra manning requirements make the weapon truly not able to be used while in port.

6. SM-1 & 2 (Surface Mode)

The primary Anti-air defense weapon for the US Navy is the Standard Missile (SM). There are several versions of this weapon both in use and currently in development. The SM-1 is used on frigates and the SM-2 (several variants or blocks) fills the magazines of all destroyers and cruisers in the fleet. The SM-2 is 15 to 26 feet in length, weighs 1,100 to 3,000 pounds (dependent upon which block) and has a surface mode range limited to the radar horizon of the launch platform. The minimum launch range is classified, but since it has a booster section it uses during the initial flight phase, it is not short enough to allow for it to be used effectively as a defense against the threat we are discussing. [Ref. 24]

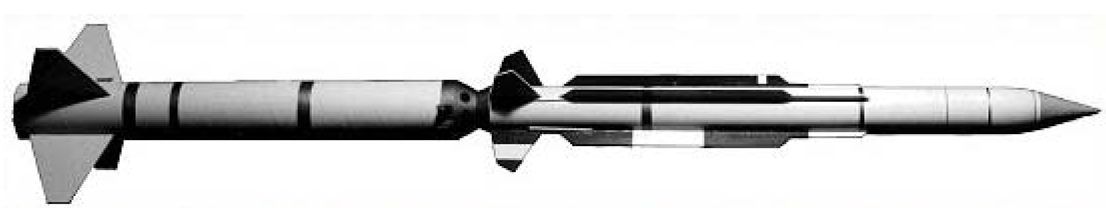

Figure 7: RIM-67 Standard Missile [From Ref. 23]

Furthermore, with a unit cost of over $400,000 each, its cost-per-kill is relatively high. This weapon, while extremely accurate against a large surface combatant within approximately ten nautical miles would be a poor choice against a target of this size.

C. GUNS

1. 5-Inch Gun

Next in our shipboard arsenal is a category that falls somewhere between small arms and missiles, the guns. The 5"/54 MK 45 Light Weight Gun Mount (LWGM) is the Navy's primary anti-surface gun battery, and Naval Surface Fire Support (NSFS) weapon. When a target is within the engagement envelope, the 5" gun is significantly more economical than a guided weapon such as a missile. The gun is also used, to a limited extent, in an anti-air defense capacity.

The 54 caliber (MK 45) lightweight gun can supposedly provide surface combatants a defense against fast, highly maneuverable surface targets, air threats and shore targets during amphibious operations. The 5-inch gun is controlled by either the MK 86 Gun Fire Control System or MK 160 Gun Computing System. Range is more than 13 nautical miles and can fire 16-20 rounds per minute. Each magazine has a capacity of 475-500 rounds. [Ref. 24] This gun is installed on Spruance-class Destroyers as well as on guided missile destroyers and cruisers.

Figure 8: MK 45 5-inch / 54-Caliber Gun [From Ref. 25]

There are those who argue that while missiles like NSSM, ESSM and RAM offer great lethality at longer ranges, a gun system coupled with both infrared and radar-based sensors is the most effective manner to combat the close-in threat posed by small boats and helicopters. [Ref. 26]

The shortcomings of this weapon against the small boat/suicide boat threat are not in the cost-per-kill category. Where the weapon is found lacking is in the measurement of the other two criteria (effectiveness and feasibility of use). When engaging a target such as a fast-moving speedboat, the gun is placed in a mode of fire called the "High-Speed Maneuvering Surface Target" or "HSMST" for short. When in this mode the system generates algorithms and uses other enhanced features in the fire control system to aid in the targeting of these fast-moving vessels. Also, High Explosive, Controlled, Variable Time (HE-CVT) rounds are used, these rounds provide a 30-foot air burst over the water and detonate above the target. [Ref. 27]

While in theory the system is designed to counter the small boat threat, there is evidence to the fact that the system lacks true lethality. Tests conducted using the *USS Donald Cook* (DDG 75), were said to demonstrate "the capability to defeat a single high-speed, maneuvering surface target simulating the patrol boat threat…" according to the testers. Further in the report there were several details that left many questions as to the accuracy or realism of the findings.

"Since the crew was fully alerted in this event, we are unable to assess whether comparable results could be achieved in a tactically realistic scenario." The report went on to say "15 percent of the rounds fired by the ship's MK 45 gun hit the target during the test. Another 24 percent were near misses." The question follows, if the crew was alerted and told what to expect, from what direction and at exactly what time; and was only able to achieve 15 percent accuracy; how well would they do if they were truly surprised? [Ref. 28] All of these points lead to questionable effectiveness of the 5-inch gun.

As we look at the "feasibility of use" criteria, there are several issues that make this weapon an unlikely choice in the environment we are discussing. When we take into consideration the fact that this gun requires the use of a radar for its targeting, requires ship's power for its operation, is only on two ship classes in the fleet and has a range of more than thirteen nautical miles we find that it is unlikely to be used while transiting in and out of port or while pier-side.

This is also a weapon that very visibly slews and elevates, this would be undesirable while either transiting through a harbor or while sitting next to a pier. If, in an extreme case, a ship did decide to use the 5-inch gun as a defense against small boats, this mechanical training and elevating is very inflexible. There are in fact many "cutouts" or areas that the gun is either limited or cannot engage at all. In the figure below the cutouts of an Arleigh Burke Destroyer with one 5-inch gun are shown. It is evident that an approach from the front or rear would make the gun nearly useless and since a ship transiting through a channel or tied to a pier is at best limited in its maneuverability- this is a significant issue.

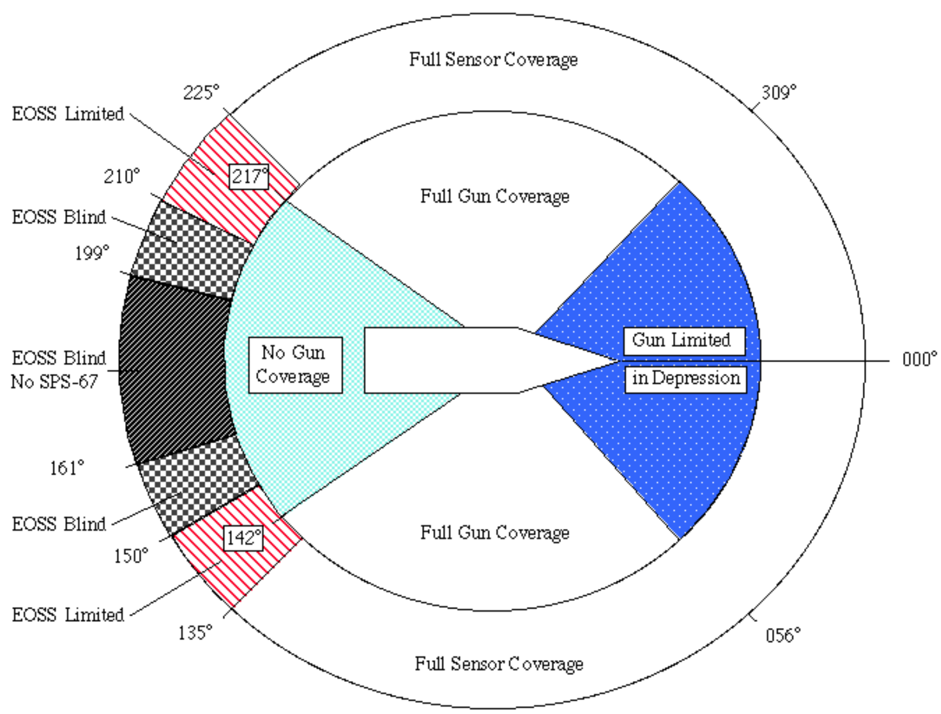

Figure 9: DDG 5-inch Gun Cutouts [From Ref. 29]

2. 76 MM (3-Inch) Gun

The MK 75 76mm gun is a lightweight, rapid-fire three-inch gun mounted on Oliver Hazard Perry-class Frigates (one gun mount each). The gun can fire up to 80 rounds per minute without reloading to a range of 10 nautical miles. This gun is remotely controlled and very accurate against small surface contacts. Since the weapon system is only on a handful of ships (of the 51 ships built for the US Navy, 33 are in active commissioned service and 10 are in the Naval Reserve Force). The "short-hull" Perry-class frigates are being retired at an advanced rate, even though they have 20 years left on their lives. As of early 2002 the Navy planned to decommission its five remaining "Flight I" (non-SH-60 capable) Oliver Hazard Perry-class guided-missile frigates by FY 2004. [Ref. 30] In total these ships will equate to roughly only ten percent of the US Navy's total surface ship force.

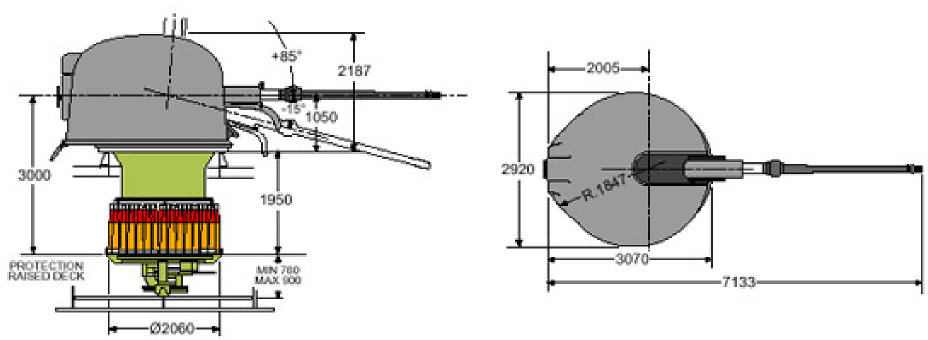

Figure 10: MK 75 76mm Gun [From Ref. 31]

This weapon system, while effective in the littoral regions and against this type of threat is still lacking in its "feasibility of use criteria." In addition to its very limited quantity, the weapon suffers from the same issue of

needing to use a radar system to generate a fire control solution for a perspective target. In the littoral environment this would not be an issue, but once the ship is next to a pier for any amount of time the radars are shut down.

The weapon system is a gun mount, and as such, it trains and elevates; this fact makes it again, an uncomfortable situation for other vessels in the vicinity. Yet another issue with the training and elevating of the mount, its position (amidships) on the frigates makes them useless for defense against a head-on or aft-on attack. The positioning of the weapon means that the gun has significantly larger cutouts than the previously referenced 5-inch guns. This lack of flexibility is significant. Similar to a number of the other weapon systems on US Navy ships, the extreme end of the engagement envelope (10nm) makes it dangerous to use while in a crowded channel or harbor.

The weapon is effective (in terms of lethality) and has a relatively low cost-per-kill, but its use is limited when in port. Given the already limited amount of space on ships, it is unlikely that this weapon system could be installed on ships other than the frigates it was designed for. The current trend seems to be that if there is any space available on a ship, a missile system will use it.

3. CIWS 1B

One of the most common weapons systems in use on surface combatants today is the *Phalanx* Close-In Weapons System or "CIWS" made by Raytheon. There have been over 870 of these units produced for twenty-one nations. The Phalanx employs

a Gatling gun consisting of a rotating cluster of six barrels. The system fires a 20mm sub-caliber sabot projectile using a heavy-metal (either tungsten or depleted uranium) 15 MM penetrator surrounded by a plastic sabot and a lightweight metal pusher. The Gatling gun fires 20 MM ammunition at either 3,000 or 4,500 rounds-per-minute with a burst length of continuous, 60, or 100 rounds from a 989 or 1,550-round magazine. [Ref. 32] The weapon is currently employed on virtually every ship in the US Navy.

Figure 11: MK 15 Phalanx CIWS (1B) [From Ref. 33]

The first version of this weapon (Block 0) was designed for defense against Anti-Ship Cruise Missiles (ASCM’s) and later saw improvements with the Block 1A version against the same threat. The newest variant, the Block 1B Phalanx Surface Mode (PSuM) allows engagement of small, high-speed, maneuvering surface craft; and low, slow-moving aircraft, and hovering helicopters. This upgrade incorporates a thermal imager, an automatic acquisition video tracker, and a stabilization system for the imager, providing both day and night detection of threats. The thermal imager improves the system's ability to engage anti-ship cruise missiles by providing more accurate angle tracking information to the fire control computer. Additionally, the thermal imaging assists the radar in engaging some ASCM’s bringing a greater chance of ship survivability. The thermal imager Automatic Acquisition Video Tracker (AAVT) and stabilization system provide surface mode and electro-optic (EO) angle track.

Operational evaluation of Block 1B, conducted aboard *USS Underwood* (FFG-36) and the Self-defense Test Ship, was completed in August 1999. According to Phalanx Program Office plans, Block 1B will be installed in 11 other FFG-7 ships between June 2000 and July 2002. [Ref. 34]

This new upgrade greatly increases the fire power available to surface ships in the fleet and perhaps most notably, CIWS-1B brings a day and night surface mode capability to this proven air defense weapon system, allowing highly responsive engagement of threats such as small boats, jet skis, and floating mines out to a range of 4000 yards.

As of November 2001 the unit cost for a CIWS 1B mount was between $6.5 and $10 million depending on the quantity and other factors. Up until that same time period the government had under contract 28 CIWS mounts. In the FY02 budget the US Navy included in excess of $40 million for additional "Block 1B kits" (upgrades to block 0 CIWS systems). [Ref. 26] In the FY 02 Budget and the FY03 Budget Submission, the US Navy has accelerated the upgrade of the CIWS system to the Block 1B variant. The FY03 Budget submission initiates a CIWS Block 1B procurement and conversion program (1B kits) geared to expeditiously deliver significantly enhanced ship self-defense and anti-terrorism/force protection (AT/FP) to amphibious ships, surface combatants and carrier force. The FY 02 and FY 03 funding plan is postured to "jump start" conversion of CIWS gun mounts to Block 1B and the objective is to provide Block 1B capability across the surface force within the FYDP. [Ref. 35]

The only exception to the apparent proliferation of this weapon is the fact that, despite the effectiveness of this new and improved version, CIWS is being slowly replaced by the RIM-116 Rolling Airframe Missiles discussed earlier. Nearly all new-construction ships will be commissioned with RAM instead of CIWS. The high cost of this weapon system could be justified by its "fit" to the threat and its effectiveness. The only criteria that the CIWS 1B could be found lacking in, is in the area of "feasibility of use."

Firstly, the fact that the weapon is being replaced by the RAM system means that it will not be on the newer ships coming to the fleet. Next, the weapon discharges 4,500 rounds per minute, while these lethal 20 mm rounds are not

sent down range indiscriminately, the possibility does exist that a handful of these rounds could make their way past the target and hit some unintended targets. Next, the system is not “stand-alone,” it requires power input from the ship as well as a pneumatic support system (air) for its operation. It must be manned remotely from either a local or remote control panel (LCP or RCP); this requirement would effectively negate the desired visual identification (VID) that would be required during an engagement such as this. This feature, while not an issue in open-ocean combat, would greatly limit the systems usability in a crowded harbor environment.

Also, while this is much less of an impact than with some other weapons systems, current placement of the CIWS mounts do have cutouts that would limit their engagement envelopes. These systems were initially placed on ships in positions that would facilitate engaging air threats. Finally, the system is quite lethal, and the lack of first person identification of the target prior to batteries release would make it difficult for the CO of a ship to comfortably leave the system loaded and in a “ready-to-go” condition in anything but an “attack imminent” situation.

4. 25 MM CHAINGUN

The MK-38 25 MM “Chaingun,” also known as the "Bushmaster," is a navy version of the externally powered weapon developed for the US Army as the Mk-242. The Mk-38 is a 25 MM automatic gun system that provides surface ships with defensive and offensive gunfire capability for the engagement of a variety of surface targets. It is designed to provide close range defense against patrol boats,

swimmers, floating mines, and various targets ashore including enemy personnel, lightly armored vehicles and terrorist threats. Only one crewman is required for operation and the maximum range is 6,000 yards (maximum effective range is 2,700 yards). The MK 38 has a maximum firing rate of 175 rounds per minute and it is loaded with a 170-round magazine.

This system consists of the M242 auto-cannon and the Mk 88 machine gun mount. The M242 auto-cannon is an externally powered, dual-feed, single-barrel weapon that may be fired in semi-automatic or automatic modes. The M242 does not depend on gases for operation but instead utilizes an electric motor to drive all the moving parts inside the cannon. Ammunition feeding, loading, firing, extraction and ejection are all done by the same motor. This motor requires ship's power to operate and thus the weapon is, to a limited degree, dependent on that power. [Ref. 36]

The relative cost-per-kill of the weapon is not an issue and so it meets this criteria quite easily. The accuracy and thus the effectiveness of the weapon is where the true issues lie. These weapons are only rarely fired, primarily due to the fact they are only installed (if at all) just prior to a deployment to the Persian Gulf or Eastern Mediterranean Sea. The accuracy of these weapons is tested by shooting at a large inflatable ball that is set adrift by the ship for the purpose of target practice, qualification and familiarization fire. Historically, the ships have had to maneuver very close to effectively engage the large, stationary target. It is logical to assume that the weapon would be less than effective against a target that is maneuvering to avoid being hit.

The issue that comes to light with respect to feasibility of use is the fact that there are just too few of these in the arsenal. Since these are not readily available, they are removed from ships immediately upon their return from deployment. For example, the *USS PRINCETON* (CG 59) was only equipped with one of these weapons prior to its 1998 Persian Gulf deployment. This single machine gun was installed in such a manner that it only provided limited coverage for one side of the ship.

Another significant shortcoming of this weapon is the lack of flexibility in its coverage. Being permanently mounted on the deck and weighing too much to move without using a crane, the weapon is limited in its coverage to that of its cutouts.

Figure 12: MK 38 25 MM Chaingun [From Ref. 37]

D. MACHINE GUNS AND SMALL ARMS

The next category and layer of defensive weapons, is the category referred to as “guns.” Like the MK 38 Chaingun above, these weapons are not guided. Once the rounds leave the weapon they are fired from they travel on the path dictated by the barrel position at the time of firing. There is no correction to the flight path once fired and thus they are considered to be “dumb weapons.” These weapons currently include:

- 50 caliber Browning Machine Gun
- 7.62 MM M-60 Machine Gun
- 9 MM Beretta Handgun
- 45 caliber Handgun
- 7.62 MM M-14 Rifle
- 223 caliber M-16 Rifle

With the exception of the “Machine Guns,” these weapons are all primarily used by Ship’s Self-Defense Force (SSDF) for protection against intruders on ships. The machine guns are used for protection against swimmers, small boats, jet skis and even land-borne threats when necessary (pier attacks).

1. 50 Caliber Machine Gun

The 50 caliber Browning machine gun has a weight of 126 pounds and is recoil operated, air-cooled, belt fed and

fully automatic. The gun has a firing rate of 450-550 rounds-per-minute and a maximum range of 7,400 yards (effective 2,000 yards). [Ref. 36]

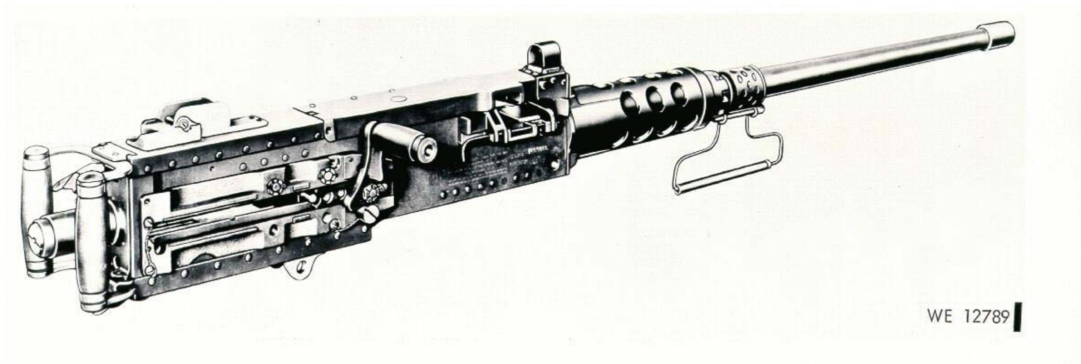

Figure 13: Browning 50 Caliber Machine Gun [From Ref. 38]

2. M-60 7.62 MM Machine Gun

The 7.62 MM M-60 machine gun has a weight of 23 pounds and is classified as a lightweight, gas operated, air-cooled, belt fed and fully automatic machine gun. The gun has a firing rate of 100-200 rounds-per-minute and a maximum range of 4,075 yards (effective 1,200 yards). [Ref. 36]

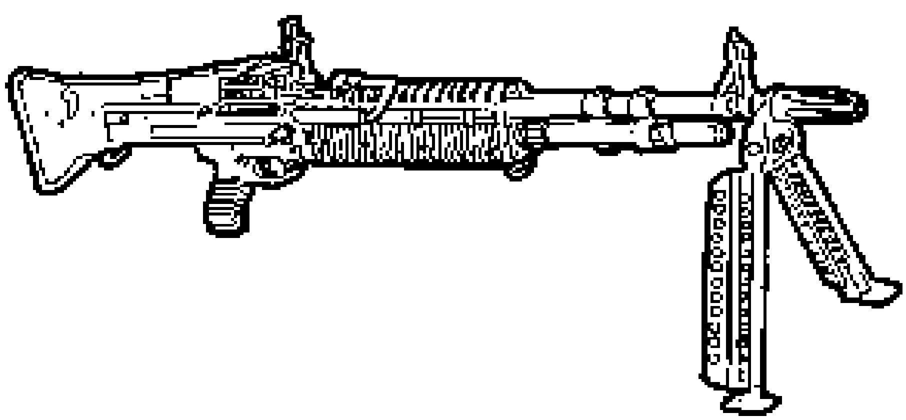

Figure 14: M-60 7.62 MM Machine Gun [From Ref. 38]

Both the above-mentioned machine guns are the current weapons of choice against the small boat threat. The problem with these systems is not their cost cost-per-kill; they are both very low cost in terms of cost to use. As far as feasibility of use, they are very likely to be employed if such a threat presented itself. The last criteria, is that of "effectiveness;" they are temporarily mounted on the decks of ships and are difficult to move in a hurry (this is more of an issue with the Browning machine gun that weighs 126 pounds). While this issue does not make them impossible to use, it does limit their flexibility to be maneuvered readily so that they can be used to engage targets outside of their cutouts.

The most significant concerns center around their lack of accuracy and lethality. The accuracy of these two weapons is subject to the aim of the sailor who is pulling the trigger. There is no guidance system to assist the weapon in acquiring, locking onto or engaging the target or threat. These weapons are unstabilized and use tracer rounds to assist the shooter in "walking-in" the rounds to the target. For several reasons, sailors are usually ineffective in their employment of these weapons. Lack of adequate practice against a threat of this type, no targeting system to speak of and lack of visibility (especially at night) all lead to this ineffectiveness.

Above that, the question of lethality is also an issue. If the rounds were to hit the target in question, their effectiveness is questionable at best. In essence, the rounds are heavy pieces of lead that are designed to penetrate light armor and have no explosive charge

associated with them. The hope is that you might hit either the personnel on the target vessel or something on it that might disable the attacker or attackers. At best, you are shooting an inaccurate weapon from an unstable platform hoping to hit a moving target in the hopes that it will be disabled or destroyed.

3. Small Arms

The last category of weapons currently in the armories of US Navy ships is small arms. This category of weapons includes 9 MM and 45 caliber pistols, 7.63 MM and 223 caliber rifles and finally the shotguns. These weapons are very inexpensive to use and there would be little hesitation in their employment against an attack. In fact, almost all ships in the US Navy arm their watch-standers with these weapons while in port.

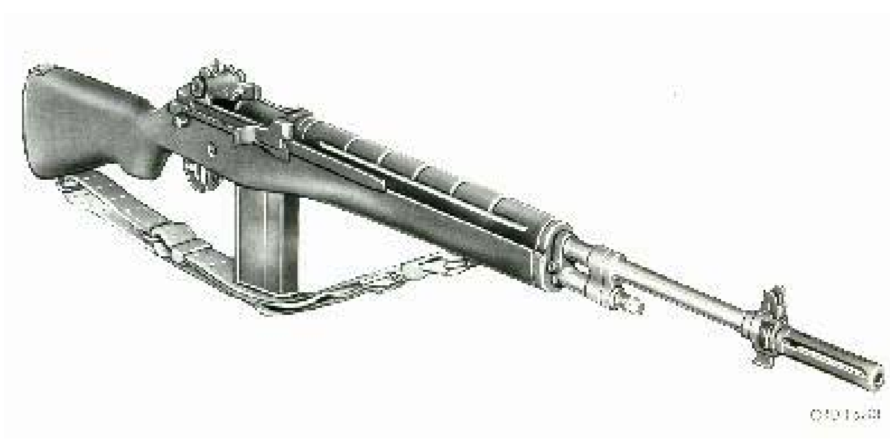

Figure 15: M-14 7.62 MM Rifle [From Ref. 38]

Figure 16: M-16 223 Caliber Rifle [From Ref. 38]

The weapons that fall into this small arms class are primarily used to deal with intruders once they are onboard the ship. These are not weapons that could be used effectively to combat the small boat/suicide attack. While highly maneuverable and very inexpensive use, they would ultimately be ineffective against a threat of the type discussed in this thesis.

Figure 17: 45 Caliber and 9 MM Pistols [From Ref. 38]

The issue or concern with these weapons is undoubtedly their accuracy and lethality. These are the most flexible

of the weapons in the arsenal due to their lightweight and ease of maneuverability. As such, they can easily be repositioned anywhere on the ship to combat a mobile threat. The drawback is that they are even less effective against a target than the previously mentioned machine guns. In the case of the machine guns, there was at least the benefit of both a substantial rate of fire and a longer range.

Figure 18: 12 Gauge Shotgun [From Ref. 38]

None of the weapons currently used in the fleet today are capable (for a number of reasons) of filling the gaps left due to relative cost-per-kill, minimum range, lethality and feasibility of use. There is a significant need for a weapon that is capable of engaging the threat effectively (destroying or disabling with one shot/one hit) while doing it within visual range (less than 1 nautical mile). A weapon is needed that is flexible in its usability and is not dependent on ship’s services (air, water, power, radars) for its use. A weapon is needed that can be seamlessly integrated into the fleet and done so in a

timely manner without the traditional statement of requirements, research and development, testing and evaluation and the timely LRIP process. The need exists for a weapon that can be delivered to the fleet in a matter of weeks or months rather than years.

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IV. ANALYSIS OF THE US ARMY JAVELIN MISSILE

A. PRESENTATION OF THE WEAPON

The Javelin Anti-armor missile is a 49.5-pound, man-portable, fire-and-forget, surface attack, anti-tank missile originally designed to counter the current and future threat armored combat vehicles. The original intention was to replace the Army and Marine Dragon missile system. The 2,500-meter range of the Javelin more than doubled the range of the Dragon. The Javelin has an advanced imaging infrared (I2R) system and a guided missile. The system's "soft launch" capability allows it to be fired from an enclosed firing position if need be. Once the missile is clear, the larger propellant in the second stage is ignited and the missile is propelled towards the target. The Javelin warhead can defeat all known armor systems. [Ref. 38]

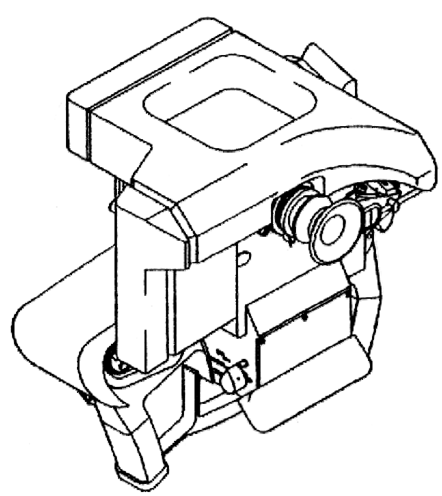

Figure 19: Javelin Command Launch Unit [From Ref. 38]

The Javelin weapon system includes a missile in a disposable launch tube and a reusable Command Launch Unit (CLU), a basic skills trainer (BST), a field tactical trainer (FTT) and a Missile Simulation Round (MSR). The CLU has a trigger mechanism as well as an integrated day/night sighting device for surveillance and target acquisition. The CLU is powered by a disposable battery with a 4-hour life and provides the capability for battlefield surveillance, target acquisition, missile launch, and damage assessment.

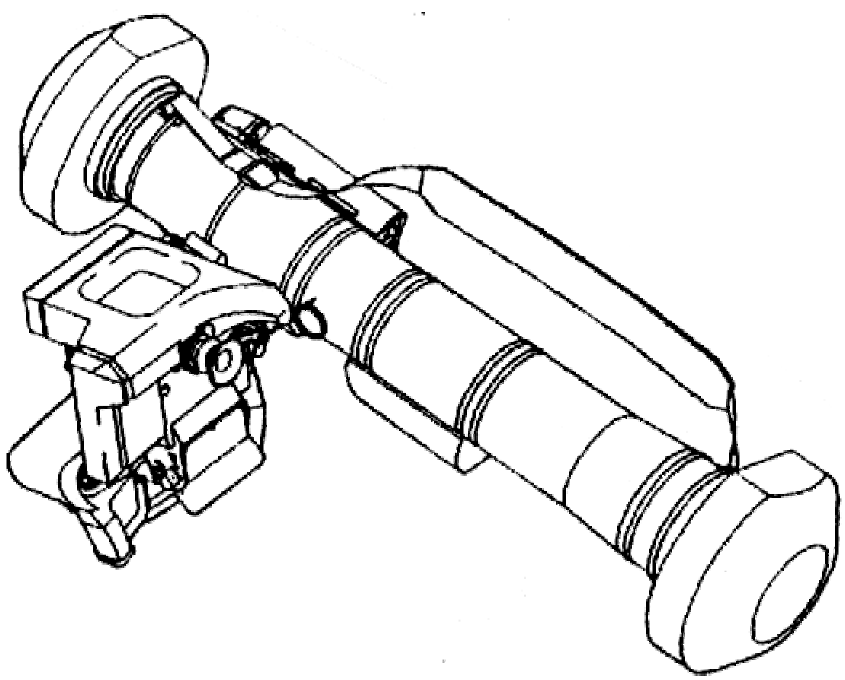

Figure 20: US Army Javelin [From Ref. 38]

The CLU houses the night vision sight (NVS). The NVS is a passive I2R system. The NVS enables observation of things that are not normally visible to the human eye. It receives and measures IR light emitted by the environment. The NVS converts the IR light into an image for the gunner. The IR image also allows the gunner to identify enemy targets.

Javelin gunners must identify battlefield combatants at night based on the images seen in the NVS. [Ref. 38]

The NVS is able to distinguish a temperature differential (ΔT) of as little as one-degree (F) up to a distance of 2,500 meters. This ΔT is represented by differing shades of green in the NVS. The sensitivity of the NVS allows the shooter to target anything with a ΔT of more than one degree compared to its background. Examples include: combustion engine exhaust, engine compartments, personnel and even hot gun barrels. [Ref. 39]

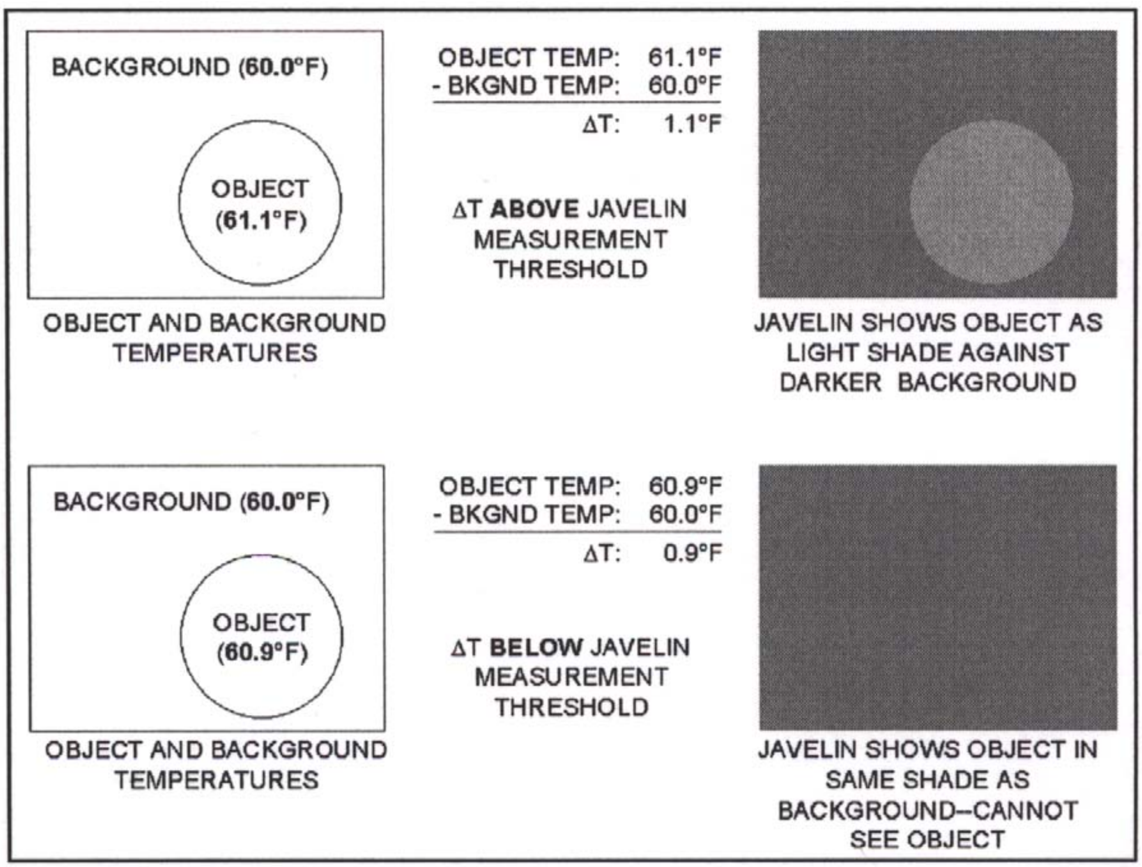

Figure 21: Measurable Delta-T (ΔT) [From Ref. 39]

The round is comprised of the Launch Tube Assembly (LTA) and the Battery Coolant Unit (BCU). The round weighs 11.1 kg, is 1.76 meters in length and has a 2.72 kg warhead with an impact fuse. The missile is divided into three functional sections: the seeker section, warhead section and the propulsion section. The missile locks on to the target prior to launch by using an infrared focal plane array and an on-board processor that maintains target tracking from acquisition, through the launch phase and continuing until detonation.

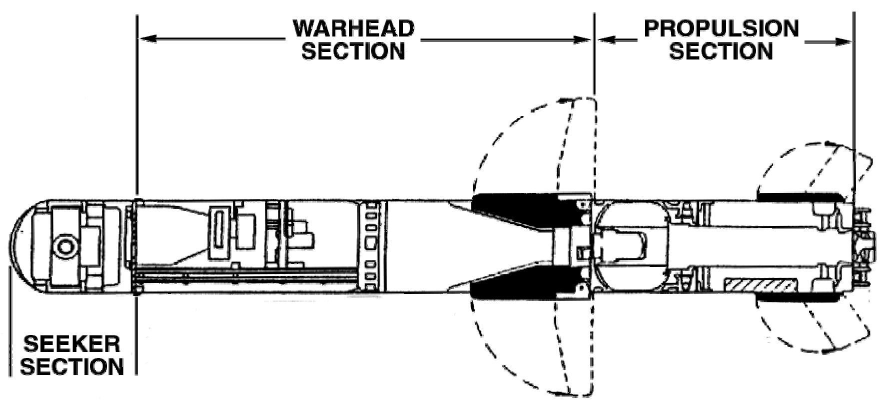

Figure 22: US Army Javelin Missile [From Ref. 38]

The BST is a device used to train personnel in the proper use of the Javelin missile. The BST is comprised of two units; the Student Station (SS) and the Instructor Station (IS). The student station is basically a simulated CLU and a missile simulation round (MSR). The instructor station is a desktop computer, a monitor, a keyboard, a mouse and a surge protector for the power supply. The BST uses actual terrain models and real visible and infrared imagery. What the trainee sees at the student station is what he or she would see in a real engagement.

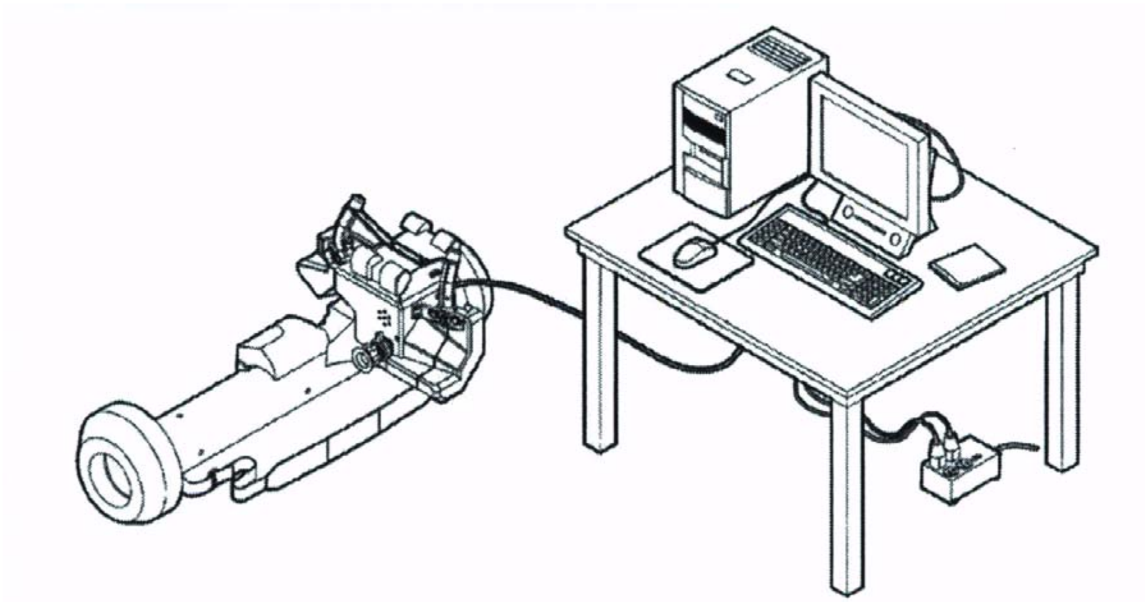

Figure 23: Basic Skills Trainer [From Ref. 39]

The Javelin missile has a “back-blast danger area” that covers 30 degrees on either side of a line directly behind the LTA when fired. This 60 degree cone-shaped danger area sector continues out to a 25 meter distance. There is a second “caution zone” that extends the cone-shaped area out to 100 meters. In addition to the back-blast danger area; debris and loose objects should be removed from the immediate vicinity, the area should be well ventilated to allow exhaust gases to escape and to prevent over-pressurization of the firing area, the amount of flammable material in the area should be minimized and all personnel within 25 meters should have hearing protection.

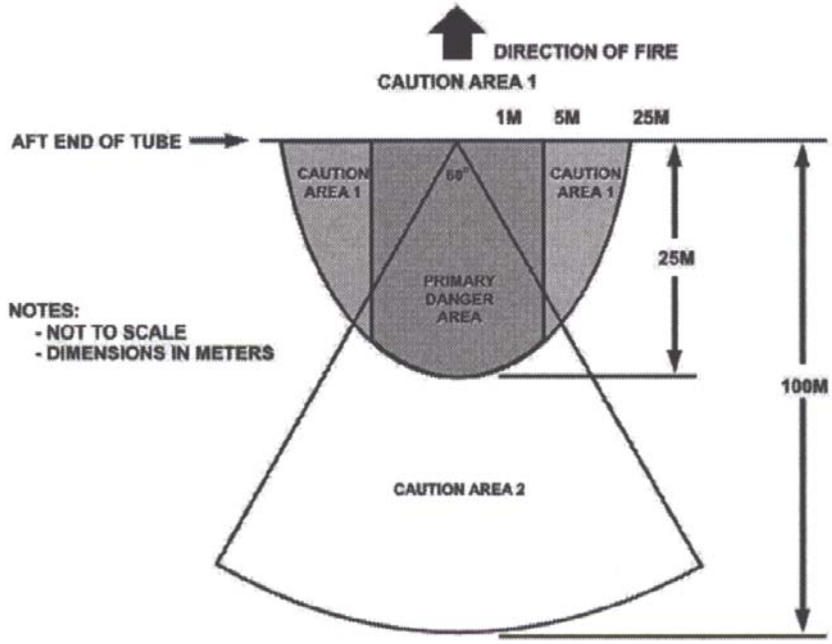

Figure 24: Javelin Back-blast Safety Zone [From Ref. 39]

The Javelin missile has two modes of attack. These modes are classified as "top attack" (minimum effective range of 150 meters) and "direct attack" (minimum effective range of 65 meters). The top attack mode is the default mode for Javelin, but the gunner can select direct attack mode prior to firing. In the top attack mode the missile approaches from above the target and detonates on top of the target. At maximum range, the missile flight path takes it to an altitude of 160 meters; this altitude varies according to the range of the target and is determined by the missiles onboard software.

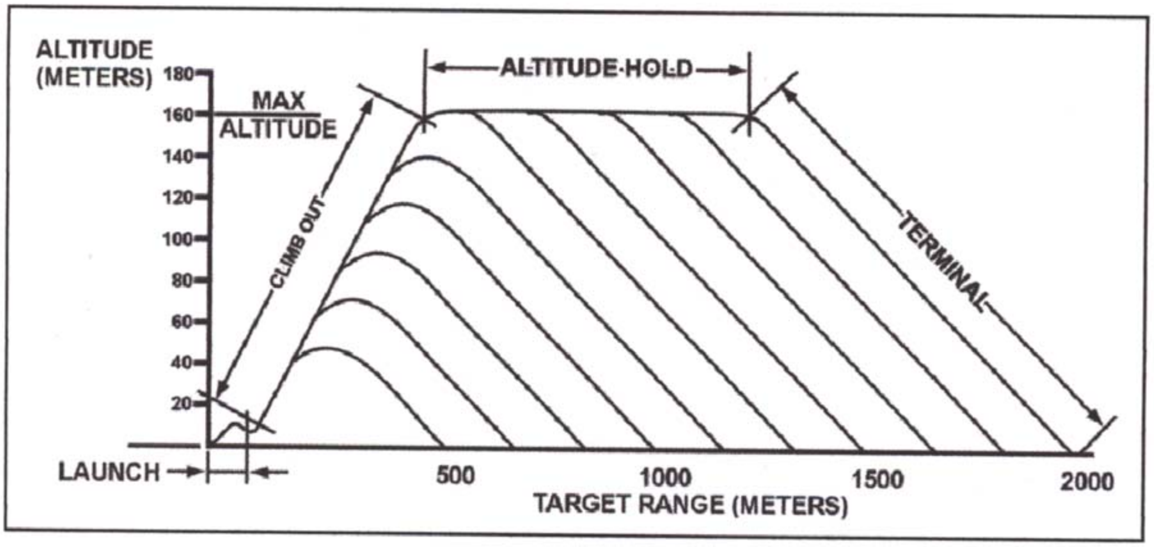

Figure 25: Javelin Top Attack Mode [From Ref. 39]

In the direct attack mode the missile flies a more direct path to the target then impacts and detonates on the side, rear or front of the target. The onboard software determines the exact flight path. At maximum range the missile reaches an altitude of approximately 60 meters. [Ref 39]

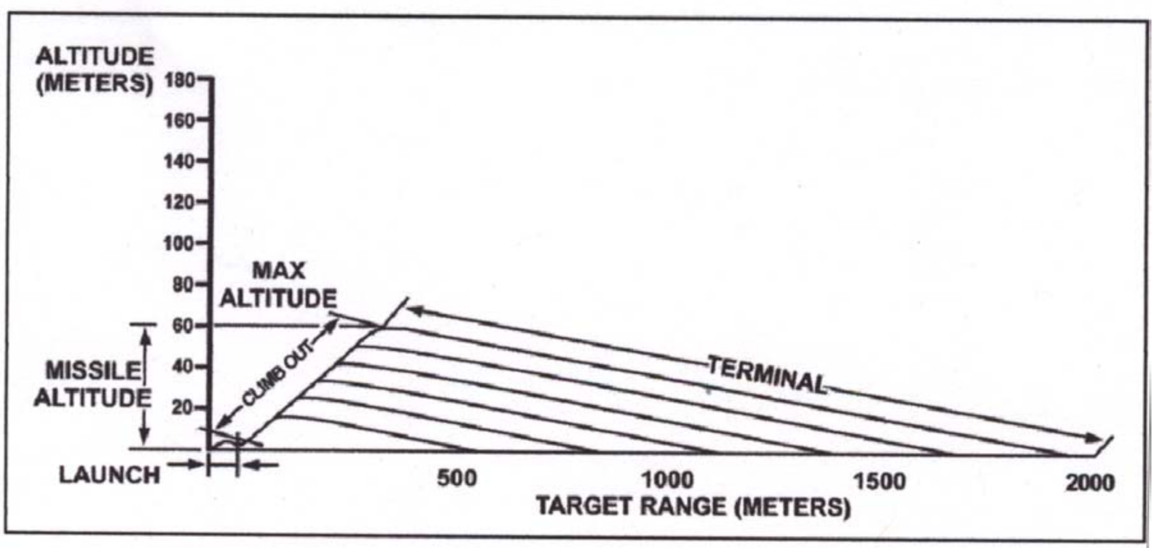

Figure 26: Javelin Direct Attack Mode [From Ref. 39]

The Javelin missile is designed to be man-portable, self-powered and lightweight (49.5 pounds). These factors allow it to be very flexible in its employment. There are three methods of carrying the Javelin: tactical, short and long distance. On a ship, the Javelin could be easily carried from one firing position to another using the tactical carrying mode. This mode, used when re-positioning and contact with the enemy is expected, the CLU and LTA are assembled and they are carried on the gunner's right shoulder with their hands on the controller and the LTA.

Figure 27: Javelin Tactical Carry Mode [From Ref. 39]

B. POTENITAL EMPLOYMENT IN MARINE ENVIRONMENT

The Javelin missile has been in production since 1994 and has proven itself to the US Army and Marine Corps. Together, they will have procured a total of 17,497 missiles as well as a significant number of CLU's from

FY2000 to FY2007. The Javelin is currently in use by Army Airborne and Ranger troops, Special Forces, Light infantry, Mechanized infantry and the Marine Corps. Since Milestone III, Full Rate Production decision, the Javelin has enjoyed ninety-three percent flight reliability and ninety-two percent "First-time gunner hits" (given a reliable round). The system has a very low life cycle cost in that its modular concept requires absolutely no maintenance and the weapon has a ten-year shelf life. [Ref. 40]

1. Mechanical Considerations

Every aspect of this weapon makes it a perfect fit for use in the maritime environment. Mechanically, the weapon is sealed and therefore corrosion would not be a significant issue. It is stand-alone and therefore would require absolutely no services from the ship to be employed. The weapon is EMI-hardened and has been rugged-ized for military use. The ten-year shelf life combined with Javelin's near zero maintenance requirements makes its preventative maintenance requirement negligible. The system has a fully functional built-in test capability (BIT) as well.

2. Tactical Considerations

The weapon requires no radar system for its employment and therefore is can be used in any environment where radar transmissions would be a concern (transiting through a channel or next to a pier). Its "feasibility of use" is

not an issue as the maximum range (2,500 meters) is such that it would allow engagement only when a target can be visually identified therefore all but eliminating accidental fratricide. The weapon will not launch if a target is not locked onto and therefore the risks of accidental discharge is eliminated. At less than fifty pounds the system is truly man-portable and its positioning on a ship is extremely flexible. This flexibility allows for 360-degree coverage without the issue of cutouts that are experienced by other point-defense systems.

The Javelin is low profile (relative to other presently available systems) and can be integrated into the already existent topside security watches on all US Navy ships with little or no impact. The footprint of the Javelin is non-existent, there is no need to sacrifice another weapon system to gain this added capability. It is both very accurate and very lethal. Its physical size would allow it to be kept in the ship's armory when not needed or required for self-defense. The weapon could also be utilized by the already existent Small Craft Action Team (SCAT), the current-day method of protecting a ship from the "swarm tactics" used by multiple small boats.

Four CLU's positioned throughout the main deck of a small ship or carried by a qualified topside security watch while in port or transiting a channel would provide more than adequate self-defense for a ship. Vessels that are traditionally unable to have any other substantial self-defense weapons such as surfaced submarines could effectively defend themselves. Vessels such as torpedo

retrieval boats and small boats from larger vessels could become effective patrol craft should the need arise.

The NVS targeting system is effective enough that the Javelin could be used at night when small arms are normally rendered useless. The NVS system can be used as an effective surveillance tool when separated from the LTA. This would provide a significant nighttime capability that is currently non-existent to ship’s self-defense force personnel using traditional image intensification-type devices. The current devices, known as night vision goggles, require a minimum amount of light to work effectively and the images lack the clarity afforded by the NVS. The images seen in the NVS by the gunner or watch stander would be incapable of being seen by the naked eye (see figures 28-30).

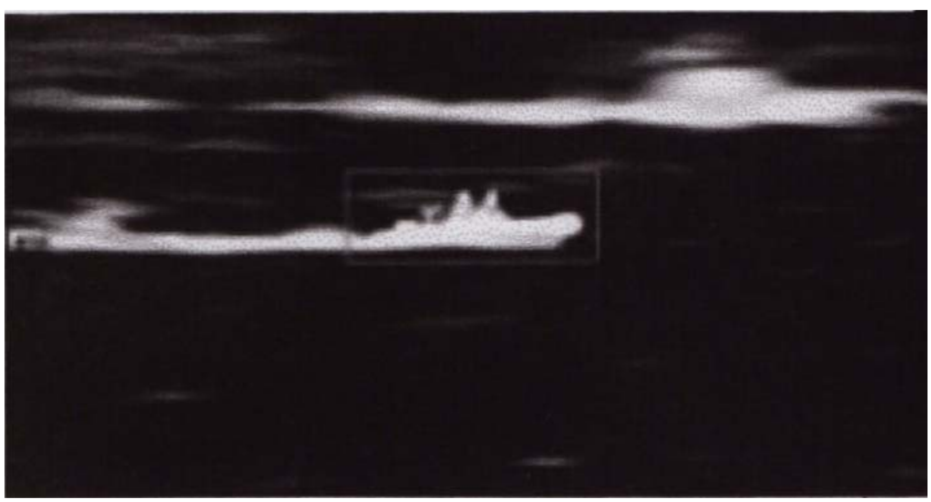

Figure 28: IR Image Rigid Inflatable Boat [From Ref. 41]

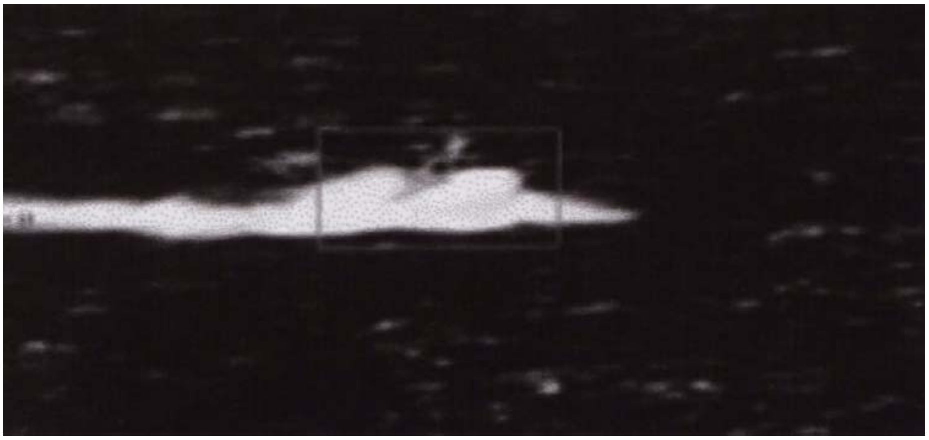

Figure 29: IR Image “Boghammer” Boat [From Ref. 41]

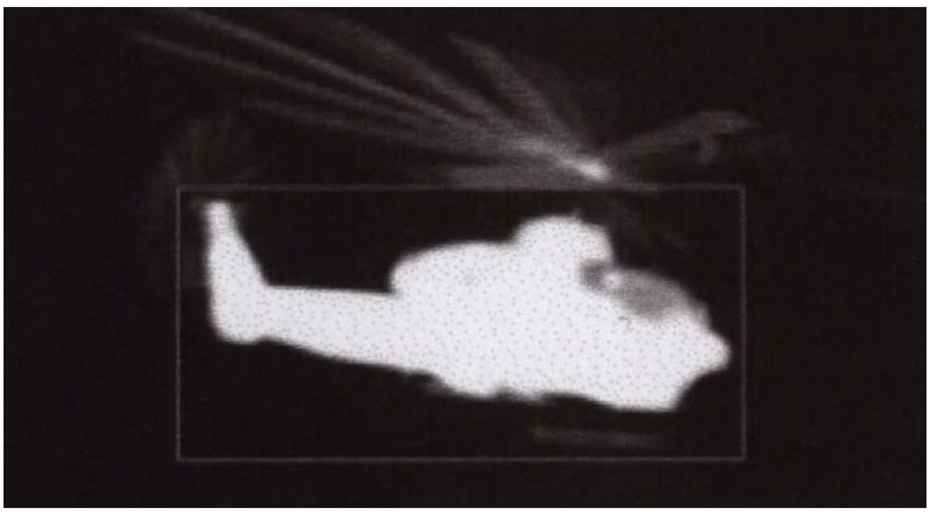

Figure 30: IR Image Helicopter [From Ref. 41]

There is significant evidence to suggest that Javelin would be a suitable and very effective weapon system if used in the marine environment. A constant temperature background, in this case a body of water, would provide a best-case scenario for targeting based on temperature differential.

The cost-effectiveness of the Javelin missile will be addressed in detail in the following chapter.

3. Comparative P^h and P^k Considerations

The Javelin missile is a proven weapon system in the land environment. Prior to determining the feasibility of its use in the maritime environment certain comparisons to current weapon systems cannot be avoided. Beyond the cost avoidance advantages that will be outlined in a later chapter, its relative lethality must be quantified and measured against existing systems. Traditional methods of quantifying lethality entail assessing a weapon's probability of hit and probability of kill (P^h and P^k). The P^h is based on:

(1) The capability of the weapon system.
(2) The accuracy of the round.
(3) The range.
(4) Gunner proficiency.
(5) Target speed, maneuverability and exposure.

The P^k is defined as the probability of killing the target if it is hit. In the case of the threat outlined in this chapter, P^k will be based on the explosive power of the round at a given range and or the penetration effect provided by the release of the round's kinetic energy.

Again, the capability of the Javelin has already been proven several times over. Several considerations combine to make engagements against enemy speedboats and suicide boats unrealistic beyond 2,500 meters. Not the least of which are rules of engagement (ROE). ROE may be the single most difficult obstacle to overcome when using any weapon

system. This portion of the thesis assumes that in the engagements discussed, the threat is real and the boats have been designated as hostile targets and thus the decision to destroy them will have already been made.

Range is a serious consideration that must be taken into account as well. It is possible to hit a small maneuvering enemy surface contact at 10,000 meters, but it is difficult to do so in a crowded harbor with numerous contacts in the vicinity. Range is also important when the fact that in an environment such as that discussed in this thesis, positive visual identification (VID) must be attained prior to engagement. Certain weapons currently in use have minimum ranges that would negate their ability to be used. Further, even given a hit, the likelihood that the target would be destroyed can range from very likely to not likely at all depending on the weapon used.

Given the limited amount of time between when the contact has been determined to be a threat and when the boat could attack or impact his or her vessel, the commander must manage his or her resources carefully. The idea is to make every round count, which requires engagement ranges favorable to the weapon in question. There is a balance. Engaging at too close a range frontally will increase the P^h and P^k, but will reduce the number of targets that can be destroyed before the attacker is upon the vessel's position.

The number of targets and non-targets affects defensive operations. Speed of the attackers presents problems as well. Speed causes more targets to be at a given point (vessel position) during a specific period. The speed of

the target also affects the ability of the weapon to successfully engage and destroy the attacker.

When comparing the lethality of Javelin to current weapon systems in the fleet certain assumptions must be made. The first assumption is that Javelin's P^h and P^k will remain identical in the maritime environment as it is in the land environment. The remaining assumptions will be outlined below table 1.

				ISSUES / CONCERNS			SUPPORT NEEDED	USABLE PIERSIDE	COST PER KILL
WEAPON SYSTEM	P^h	P^k	LETHALITY	MAX RNG	MIN RNG	CUTOUT			
Penguin (SH-60)	0.65	0.85	0.55	Y	Y	N	HELO EMBARKED	N	CLASSIFIED
Harpoon	0.35	0.85	0.30	Y	Y	N	PWR/TARGETING	N	$474,609
SM-1/2	0.20	0.75	0.15	Y	Y	Y/N	POWER/RADAR	N	$400,000
RAM	0.20	0.65	0.13	Y	CLASSIFIED	Y	POWER	N	$393,103
NSSM	0.65	0.65	0.42	Y	N	Y	POWER	N	$165,400
CIWS (1B)	0.85	0.90	0.77	N	N	Y	POWER/AIR	LIMITED	NEGLIGIBLE
3-inch / 5-inch Gun	0.30	0.85	0.26	N	N	Y	POWER/RADAR	N	NEGLIGIBLE
Machine Guns	0.20	0.20	0.04	N	N	Y/N	NONE	Y	NEGLIGIBLE
Small Arms	0.05	0.05	0.00	N	N	N	NONE	Y	NEGLIGIBLE
Javelin	0.92	0.90	0.83	N	N	N	NONE	Y	$65,000

Table 1. Relative Comparison of Weapon Systems

The following is a list of assumptions that were made in table 1. Cost-Per-Kill is computed assuming that one shot or burst of shots equates to one kill. This assumption reflects best-case scenarios for each weapon system. It assumes engaging a target at the optimum range that would result in maximum weapon effectiveness. SM-1 launchers on frigates and the first five Ticonderoga-class cruisers (MK 13 and MK 26 launchers) are subject to launcher cutouts.

CIWS (1B) placement on ships severely limits its use when pier-side. P^h and P^k values for all weapon systems except Javelin are estimates based on input from a number of sources. Javelin P^h and P^k values utilize actual values. Lethality values are limited to two decimal places.

As the table 1 reflects, Javelin has a lethality value of .83 compared to the next highest value of .77 in the case of CIWS. Javelin has the lowest relative cost per kill ($65,000) of weapons without cutout limitations. Additionally, Javelin is the only weapon that meets all of the following criteria: A lethality of greater than .80, has no cutout limitations, has no range envelope limitations or concerns, requires no shipboard support systems and can be used pier-side.

V. COST ANALYSIS OF JAVELIN

A. ACQUISITION PROCESS

The acquisition process used to acquire the Javelin missile was innovative in its design and ambitious in its cost-savings goals from the very start. In 1986, the program management office developed an acquisition strategy designed to encourage competition during each phase of the program. These phases included a Demonstration/Validation (DEM/VAL) phase, a fly-off phase, Engineering and Manufacturing Development (EMD) phase and a competitive production phase.

The Javelin program began its DEM/VAL phase in August of 1986 with a 27-month proof-of-principle (POP) and fly-off phase to evaluate three separate technology concepts: the laser beam rider system (Ford Aerospace/General Dynamics Corporation), imaging infrared seeker with fiber optic guidance (Hughes Aircraft Company/Honeywell) and the imaging infrared fire and forget seeker (Texas Instruments/Martin Murietta). Each of these companies was awarded a $30 million firm-fixed price contract to develop a prototype and demonstrate its performance. This method of demonstrated performance was critical to the overall cost reduction efforts.

After completion of the POP a fly-off was conducted and the best system would be chosen for the EMD phase. The best system would be the one that best met the user's needs and technology requirements, while still providing the best cost, lowest risk and best schedule. The end result would be that there would be two qualified sources for full rate

production. This competitive contractor teaming (CCT) or joint venture (JV) would continue on into the EMD phase. [Ref. 43 and 45]

In June of 1989 the EMD phase began with a cost-plus-incentive-fee contract awarded to Texas Instrument and Martin Marrieta (TI & MM). This contract allowed for the option of two low rate initial productions (LRIP). The goal of having MM and TI co-develop the system was to have them prove their production capabilities during the LRIP phases and then have them compete with each other for the full rate production phase (FRP) for a 60/40 split. The result would be that the DoD would benefit from both the reduced risk (having two sources) and the economic benefits of competition between two contractors.

There were additional risk-reducing efforts in the contract verbiage as well. As a result of the nature of joint venture contracting, the responsibilities and thus the risk would be divided equally between the two contractors. The joint venture contractors would direct all sub-contracting and the government-furnished items would be limited. The president of the joint venture was appointed from TI and a vice-president was appointed from MM.

Critical components were identified and were then required to be available from two independent sources. This dual sourcing would allow for reduced development risk and low unit pricing due to competition. The critical components identified for this second sourcing would be the focal plane array (FPA), Electronics Safe Arm and Fire (ESAF), launch tube assembly (LTA), rate sensors (also

referred to as the gyro) and the on-board vessel (OBV). [Ref. 43]

While the efforts to save costs were substantial, there were significant issues that forced the cost of the program to increase and the benefits of joint venturing to decrease. The Javelin missile system experienced technical difficulties in items such as the propulsion unit, ESAF, missile and CLU FPA, batteries and even total system weight. Combined, these difficulties led to cost overruns and schedule delays.

From June 1989 (EMD awarded) until September 1991 the cost of the program increased 260 percent from the original estimate from the contractor. There were other issues as well; the "right-sizing" and budget cutbacks also impacted the program as well. The Army procurement quantity went from 58,000 down to 26,600 missiles and the CLU quantities decreased from 5,000 to 2,800. The Marine Corps also was impacted and their procurement decreased from 12,550 missiles to 4,669 and their procurement of CLU's went from 1,486 to 464. Ultimately, the total cuts more than halved the original quantity estimates. An additional restraint was placed on the program when the procurement program was extended from a 6-year production to a 10-year one; and then finally a 14-year procurement plan. [Ref. 43]

As a result of the many issues outlined above, the Deputy Undersecretary of Defense (Acquisition and Technology) requested that the PM investigate present a Cost Reduction Plan for the program. The implementation of the plan resulted in a cost savings of $1.4 billion and drastically impacted the joint venture strategy originally

pursued. Of note was the decision to maintain the joint production into a third LRIP phase, FRP, two multiyear contracts, increase in government-furnished items and reducing the 14-year program to an 11-year contract. [Ref. 43]

In the early stages of Javelin development, the total invested in RDT & E was $768 million (then-year dollars). Prior to FY2003, the total procurement cost $2.399 billion dollars (TY$). The following table will reflect yearly procurement of Javelin by fiscal year for the US Army. An additional 2,533 missiles and 418 CLU's were procured by the US Marine Corps (the USMC procurement program ended in FY01). [Ref. 40]

YEAR	QTY PROCURED / PROPOSED
FY2000	2,392
FY2001	2,776
FY2002	4,139
FY2003	1,478
FY2004	1,368
FY2005	1,451
FY2006	0
FY2007	1,322
TOTAL	17,318

Table 2. Javelin Missiles in the Field [After Ref. 40]

B. POTENTIAL SAVINGS IN COST AND TIME

The fact that $2.399 billion has been spent in the research, development, testing, evaluation, fielding,

logistics support and program office management is not a concern with respect to the purpose of this paper. Rather, the purpose is to establish that the DoD can benefit from the “sunk cost” already invested in the project. If the US Navy were to determine that the Javelin missile has a place on naval vessels for the purposes of anti-terrorism and force protection (AT/FP) then it could reap incredible benefits from the time and money invested by its Army and Marine Corps counterparts.

As stated earlier, the acquisition of a new weapon system is a process that is necessarily long and very expensive. These time and cost factors are necessary to verify that the potential system is necessary, feasible, functional, affordable and ultimately, field-able. These costs and delays are usually necessary if the weapon system is being developed from a set of new requirements generated for the purposes of fielding a new weapon system.

The principle point of this thesis is to establish that there is a need for a system such as Javelin in the maritime environment. Javelin has proven itself as a functional and reliable weapon. It has proven itself to be accurate and very functional even for first-time users. As for cost efficiency, the “per unit cost” of $68,500 per missile and $104,000 per CLU, is relatively inexpensive. The question of whether or not the weapon can be fielded, has again, already been answered by the Army and Marine Corps. The weapon is already in the supply system; as a result the logistics portion of the fielding requirement has already been met.

There are Javelin training courses (010-ASI2C) already in existence at a number of installations. These courses are designed to teach the unit medium range anti-armor weapons specialist the basics of the Javelin Weapon System, preparation for firing, how to restore to a carry configuration, carrying techniques, infrared principles, target engagement procedures, target engage-ability, warning indicators and malfunctions procedures, field tactical trainer operations and maintenance. The gunner is evaluated using the BST and the field tactical trainer. [Ref. 39]

To add to the Javelin's case of field-ability, the weapon has already been field tested, rugged-ized, approved for military use, proven safe from the hazards of electromagnetic radiation to ordnance or "HERO-safe" (specifically in the land environment) and the logistics support system is already in place [Ref. 44]. The Javelin's 10-year shelf life and its near-zero maintenance requirements make it an almost off-the-shelf acquisition for employment on Navy vessels.

The majority of the cost savings would come from the negation of RDT&E dollars, $768 million in the case of the Javelin missile. Add to that the cost avoidance associated with entering/continuing the acquisition process late in the learning curve; and the total savings would be tremendous in terms of actual dollars. Also, taking into consideration the 14 years of program maturity, the Navy would realize both financial and schedule benefits.

C. FIELDING PROPOSAL

The current fleet size and composition is illustrated in table 3 below. As both actual battle force vessels as well as the support vessels would be considered as targets by an attacker, both categories have been included in the proposal.

SHIP CLASSIFICATION	BATTLE FORCES	MISC DEFENSE FORCES
Aircraft Carriers	12	
Fleet Ballistic Missile Submarines	18	
Surface Combatants	105	
Nuclear Attack Submarines	54	
Amphibious Warfare Ships	40	
Combat Logistics Ships	31	
Support/Mine Warfare Ships	32	74
Active Reserves	14	9
Strategic Sealift		67
SUBTOTALS	306	150
TOTAL	456	

Table 3. Ships of the US Navy [After Ref. 42]

The fleet totals 456 vessels, 306 of which are what would be considered to be high profile or primary targets. However, the remaining 150 miscellaneous defense forces should be considered to be potential targets as well. While the 72 submarines might seem to be out of place on a list of vessels requiring a surface-to-surface point-defense system; the author submits that these are among the most vulnerable on the list. The fact that submarines are limited to only the small arms on board for self-defense

combined with the fact that they must enter and exit port surfaced make them a very attractive target for an attack from a small boat. Table 4 below shows the weapons systems currently available on US Navy vessels for defense against small boats. As the table shows, not all weapons are available on all vessels. More significantly, some vessels have only small arms available for defense against small boat attacks.

	Penguin (SH-60)	Harpoon	SM-1 / 2	RAM	NSSM	5" Gun	76 MM Gun	CIWS (1B)	25 MM	.50 Cal/M-60	Small Arms
Aircraft Carriers	X				X			X		X	X
Ballistic Missile Submarines											X
Surface Combatants	X	X	X		FEW	SOME	FEW	X	FEW	X	X
Nuclear Attack Submarines											X
Amphibious Warfare Ships				SOME	SOME			SOME	FEW	X	X
Combat Logistics Ships											X
Support/Mine Warfare Ships										X	X
Active Reserves					SOME					X	X
Strategic Sealift										X	X

Table 4. Weapons on US Naval Vessels [After Ref. 38]

The fielding proposed for the Javelin missile into the fleet would be one that would take into consideration the size of each vessel, marine component available on each vessel and also the space available on each as well as adequacy of coverage. The proposal for the quantity of "Sea Javelins" to be fielded would be as outlined in table 5.

VESSEL TYPE	QTY	(PER SHIP QTY)				TOTAL		
		CLU's	Rounds	BST/MSR		CLU's	Rounds	BST/MSR
Aircraft Carriers	12	8	32	1		96	384	12
Ballistic Missile Submarines	18	2	8	0		36	144	0
Surface Combatants	105	4	16	1		420	1680	105
Nuclear Attack Submarines	54	2	8	0		108	432	0
Amphibious Warfare Ships	40	6	24	1		240	960	40
Combat Logistics Ships	31	2	8	1		62	248	31
Support/Mine Warfare Ships	106	2	8	0		212	848	0
Active Reserves	23	4	16	1		92	368	23
Strategic Sealift	67	4	16	1		268	1072	67
TOTALS	456					1534	6136	278
BST UNIT COST= $63,803		COST PER ITEM:				$104,000	$68,500	$66,139
MSR UNIT COST= $ 2,336								
BST/MSR COST= $ 66,139		TOTAL COSTS/ITEM				$159,536,000	$420,316,000	$18,386,642
		TOTAL FIELDING COSTS				$598,238,642		

Table 5. Proposed Fleet Fielding and Cost Projection

With an estimated total cost of $598,238,642 the Javelin missile represents an incredible cost avoidance opportunity to the DoD. The total fielding cost would deliver a capable, tested and lethal weapon at a fraction of the cost the Marine Corps and Army paid to develop the same weapon. A fielding mix such as that illustrated in table 5 would allow a significant number of Javelin missiles to reach the fleet and provide adequate coverage for each vessel. The BST’s (which include the cost for the MSR’s) would not be necessary for the submarines due to the space considerations on those types of vessels; the BST’s could be utilized at the squadron level for qualification and training purposes.

An additional expense that would be incurred in the fielding of the Javelin missile on naval vessels would be the software needed to both validate its use in the maritime environment and to train personnel. This cost would be incurred in the procurement of any newly developed system. The estimated cost of generating or modifying simulations to reflect sea/ocean backgrounds and targets would be $330,000. The Javelin Program Office is in the initial stages of planning and budgeting for this now. [Ref. 40]

The Navy could potentially benefit from a reduced unit cost based on economic order quantity discounts if the fielding were to be spread over a number of years. The production capabilities of the contractors might also be an issue leading to this course of action. Currently the rate of production for CLU's is 65 per month and 440 per month for the rounds. [Ref. 45] In either the case, the fielding and training of the Javelin missile could be modified so that it would equip the ships that are most vulnerable first. This list would include submarines, ships deploying overseas and vessels with the least self-defense capabilities.

The procurement quantities listed in table 2 are based on the quantities in the FY 03 President's Budget with the Appropriation Conference Committee's marks. In reality, the numbers in FY 03 reflect the quantities in the last year of Javelin's second multi-year contract. The notional quantities in FY 04, FY 05 and FY 07 reflect what will be a single-year contract in FY 04 with option in the following years. FY 06 will depend primarily on foreign military

sales (FMS) to make up for the potential drop in production (zero).

D. PROCUREMENT PROPOSAL

The Navy has three immediate options available to potentially procure the Javelin missile in the FYDP (estimate quantities to be 6,136 Rounds, 1,534 CLU's and 278 BST/MSR combinations):

> 1) The Navy could enter the procurement process immediately and purchase CLU's, BST/MSR's and rounds under the current (FY 2003) contract being executed and potentially take advantage of some type of economic order quantity discount.
>
> 2) The Navy could enter the procurement process at the tail end of the current procurement plan in the President's Budget and currently under contract negotiation (through FY 2007) and attempt to procure the Javelin during FY 2008.
>
> 3) The Navy could procure its total quantities during the FY 2006 FMS-dependent year where procurement estimates are currently zero. This scenario would allow for the negotiation of a multi-year contract where a twelve to thirteen percent savings could be realized (historic cost savings realized with multi-year contracts).

The first proposal, which would allow for the quickest implementation into the fleet, is the least feasible. There are time constraints involved and FY 03 has already begun.

There are some nineteen or twenty contractors involved in the production of the Javelin and the lead-time is between twenty-four and thirty-one months. Furthermore, the potential cost avoidance from an economic order quantity discount would not likely be realized at this late date. It would be difficult if not impossible to implement this proposal. If the need for the weapon was realized and its procurement was decided upon in an expeditious manner, the quantities would need to be modified and the fielding of the Javelin to the fleet would need to be prioritized. It is unlikely that there would be any cost avoidance realized; in fact it is very likely that it would be more costly to procure any significant quantity with such short notice.

In the second proposal, the Navy would attempt to procure its Javelin procurement quantities during FY 08. This would have to be decided no later than 2004 to be entered into the FY 05 President's Budget. The previously mentioned lead-time would require this type of advanced planning. There would be no cost avoidance due to the fact that this would be yet another single-year contract. While this option would allow for sufficient planning and would still procure weapons for deployment to the fleet, it would not realize any per-unit cost avoidance. The DoD would still realize the benefits of avoiding the substantial sunk RDT&E costs and the even longer time delay in acquiring a weapon from inception through full rate production.

The final proposal would allow for both the best-case and second-best-case scenarios. If the procurement quantities could be approved and the fielding agreed to in time, then the DoD could benefit from converting three

(best-case) or two (next-best-case) single-year contracts into a single multi-year contract. The best-case scenario would allow for FY 04 through FY 07 to be converted into a single multi-year contract with the Navy procuring its Javelins in FY 06 and both the US Army and Navy benefiting from the twelve to thirteen percent cost savings historically associated with multi-year contracts.

In the second-best-case scenario, FY 04 procurement quantities will have already been contracted and the contract for the remaining years (FY 05 through FY 07) could be combined into a single multi-year contract (three years vice four). [Ref. 46] Again realizing the economic benefits of multi-year contracts, albeit, to a lesser degree. The best-case scenario is illustrated below:

(USA FY 04 to FY 07 FIELDING COST)	**$520,813,570***
+	**+**
(USN PROPOSED FLEET FIELDING COST)	**$598,238,642#**
DoD FIELDING COSTS TOTAL	**$1,119,052,212**
X	**X**
MULTI-YEAR EXPECTED CONTRACT SAVINGS	**13%**
= TOTAL COST AVOIDANCE	**$145,476,788**

*USA FY04 to FY07 fielding cost based on 4,141 missiles X $125,770 each

#USN Proposed fielding cost based on Table 5

The end result would be that the US Navy and the US Army would both realize cost avoidance benefits from the procurement of Javelin missiles for naval vessels. The maximum contract length would be five years due to current

acquisition and procurement restrictions. Also, there would have to be consideration given to the maximum production rates for both the CLU's and the rounds.

Beyond the financial advantages outlined above, procuring the Javelin for the Navy would provide significant benefits in streamlining the time to acquire a much-needed weapon. The time normally spent conducting threat analysis, generating a mission needs statement (MNS), performing an analysis of alternatives (AOA), creating an operational requirements document (ORD), passing through the test and evaluation phases and passing through all the required milestones could be greatly accelerated.

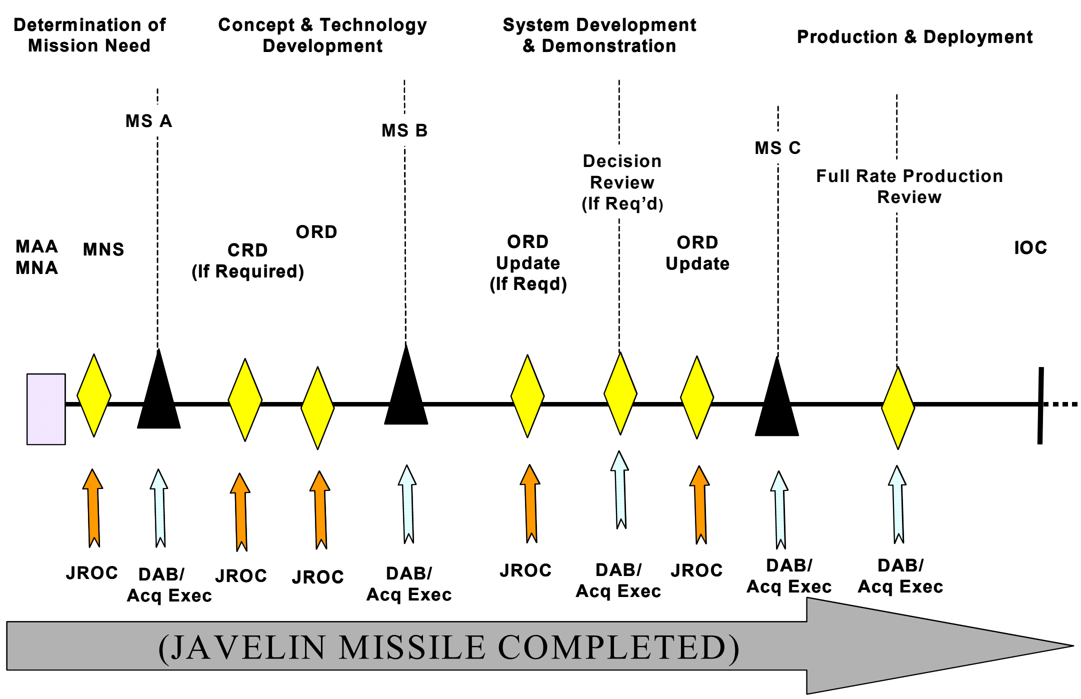

Figure 31: Requirements & Acquisition Process [From Ref. 47]

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The intent of this thesis was to examine the need for a stand-alone, point-defense weapon for use on surface vessels and surfaced submarines while entering and exiting ports, while in restricted waters and while pier-side where ship’s self-defense weapon systems are usually powered down or in an otherwise unusable state. This thesis provided a real life analysis of the current self-defense weapons of US Naval vessels against the small boat and suicide boat threat. This thesis hopes to serve as a roadmap for a more in depth analysis of alternatives for this mission area. The author has systematically reviewed all existing weapon systems currently available to combat this threat. The existing weapon systems were analyzed with respect to their relative cost per kill, lethality and feasibility of use. Additionally, this paper analyzed the potential suitability and effectiveness of the US Army Javelin Missile to counter this threat.

This paper further analyzed the cost that the US Army has invested in its acquisition of the Javelin missile. Ultimately, the goal of this thesis was to illustrate how both the US Navy and Army could benefit from a strategic financial partnership in the procurement of Javelin missiles for naval vessels. This benefit would be in the form of a thirteen percent cost avoidance for both. In short, the intent was to identify areas where US DoD can realize a tremendous cost avoidance while attaining a

substantially improved self-defense capability against this emerging asymmetric threat with minimal financial impact.

The weapon systems currently employed on most US Naval vessels were designed with a vastly different mission area in mind. The blue water open ocean threats that these weapon systems were designed to counter, while not gone entirely, are not the most likely to be used against our ships and submarines today. The US has achieved relative dominance in the traditional maritime warfare areas. As a result of this dominance there has been a rise in the development and use of asymmetric warfare tactics.

The DoD could benefit significantly with respect to both cost avoidance and schedule advantages in the fielding of a weapon system that is able to combat a new and prolific threat. These benefits should be taken advantage of at the earliest opportunity and the methods to do so will be outlined in the following section.

B. RECOMMENDATIONS

1. Contracting

The US Navy should work in an expeditious manner with the Javelin Program Contracting Office in order to take advantage of the current contract negotiations, which are scheduled to be finalized in February of 2003. The advantages are that the currently proposed single-year contract (with options) could be extended into a longer multi-year contract in order take advantage of the multi-year contract benefits outlined in chapter V.

Additionally, there would be no dependence on foreign military sales in FY 06. If the FMS's do not occur, then

any further procurement of the Javelin missile will be required to go through the "proving phase" as the production line will have been shut down for more than one year. Both the US Army and Navy would benefit from the additional quantities of missiles and CLU's.

Additional benefits include ease of integration of the weapon system in to the fleet. The logistics and training portion of the entire program are already in place. The sunk cost of RDT&E can be taken advantage of as well.

2. Software Development

Javelin Program Office should work with US Navy personnel in order to develop a robust training library for the training pipeline that would include engagement scenarios against the numerous types of attack craft available. This library should include rubber rafts, jet skis, rigid-hulled inflatable boats, Boston whalers, fishing vessels and patrol craft. This software would serve two purposes; firstly, it would allow for a detailed analysis of the performance of the weapon system in a marine environment. Issues such as vessel wake, sun reflection, optimum missile flight mode and maximum target speed could be identified and addressed through software simulation. Secondly, the software would serve as a training aid to be used when the Javelin has been delivered to the fleet.

3. Field Testing

Naval Surface Warfare Center, Dahlgren should begin generating testing criteria and scenarios to evaluate the Javelin against the target-types of interest. This would provide real-life environment testing and determine if there are any limitations in the marine environment. The results of this testing should be documented and integrated into the training curriculum that would eventually be developed.

4. Fielding

The final recommendation of this thesis would be the fielding of the Javelin missile itself. That fielding could be in accordance with the fielding proposal in chapter V or another manner as determined by budget procurement quantities and or testing results. Concurrent with testing and integrated with fielding, tactics should be developed on how best to utilize the Javelin and integrate it with ship's self-defense force personnel. These tactics should be discussed, tested and documented in order to have standard phraseology and methods of use in the fleet. Qualification standards should be developed and promulgated to the fleet as well as Navy Enlisted Classification (NEC) codes and requirements.

LIST OF REFERENCES

1. Scott,R., "UK Plans to Counter Terrorists at Sea" Jane's Defence Weekly, 19 June 2002

2. Smith, Charles., "Is Navy Prepared for Terrorist Attacks?"(http://www.worldnetdaily.com/news/article.asp?ARTICLE_ID=20646) 13 October 2000

3. Pate, C.A., *Javelin: A Case Study in Model-Test-Model*. Master's Thesis. Naval Postgraduate School. Monterey, California. December 1992.

4. Bellman, E., "Sailors Who Watch for Peril Must Now See It With Their Eyes- To Threats on the Horizon, Add Exploding Dinghies; Scrutinizing Every Blip" The Wall Street Journal. 18 October 2001

5. Ripley,T., "Developments of the Decade" (http://www.global-defence.com/1998/97/DefencePower.html)

6. Gordon, M. R., "Superpower Suddenly Finds Itself Threatened by Sophisticated Terrorists" The New York Times, 14 October 2000

7. Author unknown, "Asymmetric Warfare, The USS Cole, and the Intifada" (http://www.theestimate.com/public/110300.html) 03 November 2000

8. Kennedy, H., "Services Trying to Pump New Life Into Aging Gear" http://www.nationaldefensemagazine.org/article.cfm?Id=428) February 2001

9. Sniffen, M. J., "Bomb Materials ID'd" (http://abcnews.go.com/sections/world/DailyNews/Cole001101_2.html), 01 November 2000

10. Staff and Wires, "Suicide Squad in Sri Lanka Sea Battle"(http://www.cnn.com/2001/WORLD/asiapcf/south/09/16/srilanka.armada/index.html), 16 September 2001

11. Berkowitz, S., "Worldwide: DoD Personnel Killed in Terrorist Attacks- A Review" The Guardian, v. 01-03 p. 9, October 2001

12. "AGM-119B *Penguin* Anti-Ship Missile" (http://www.fas.org/man/dod-101/sys/missile/agm-119.htm) 26 November 1999

13. Austin, P.F., "Why are our ASM's smaller than theirs?"(http://yarchive.net/mil/naval_missile_size.html) September 1998

14. Wikipedia, The Free Encyclopedia, "Tomahawk Missile"(http://www.wikipedia.org/wiki/Tomahawk_missile) July 2002

15. US DoD FY 2003 Budget Estimates, Defense Emergency Response Fund. p. 75. (http://www.dtic.mil/comptroller/fy2003budget/budget_justification/pdfs/derf/fy2003_derf.pdf) February, 2002

16. "BGM-109B Tomahawk Anti-Ship Missile" (www.index.ne.jp/missile/ gif/tomahawk.gif)

17. Pietsch, P.M., *War-At-Sea or War From the Sea?* Master's Thesis. Naval Postgraduate School. Monterey, California. 1993

18. Navy Fact File, "Harpoon Missile" (http://www.chinfo.navy.mil/navpalib/factfile/missiles/wep-harp.html) November 2000

19. Valkyrie Arms, "Harpoon Missile" (http://www.valkyriearms.com/images.htm) November 2002

20. "RIM-116 Rolling Airframe Missile System", (http://navysite.de/launcher/ram.htm) June 2002

21. "RIM-7 Sea Sparrow Missile" (http://www.fas.org/man/dod-101/sys/missile/rim-7.htm) November 1999

22. Naval Sea Systems Command Public Affairs, "First Full Production Round of Evolved Sea Sparrow Missile Delivered," *Navy Newstand*

(http://www.news.navy.mil/search/display.asp?story_id=3496), Story Number: NNS020911-0714 September 2002

23. Standard Rim-67A Surface-to-Air Missile www.commonwealth.net/rockets/ lpad/planstandardrim.htm October 2002

24. "MK 45 5-inch / 54-caliber (lightweight) gun" (http://www.fas.org/man/dod-101/sys/ship/weaps/mk-45.htm) November 1999

25. "MK-45 Gun" (http://users.visi.net/~markmcb/Images/Weapons/MK-45.jpg) October 2002

26. Keeter, H., "Navy To Steer On Ship Self Protection Soon," *Defense Daily*, v. 212, No. 26, p. 1, 6 November 2001

27. "MK 45 MOD 4 Naval Gun System" (http://peos.crane.navy.mil/pdfs/MK%2045.pdf) October 2002

28. McCarthy, M., "Testers Question Navy Defenses Vs. Small Craft," *Defense Week*, v. 22, No. 12, p.1, 19 March 2001

29. "Combat Systems - 5" Naval Gun (5"/54) - Systems Description(SD)"(http://www.bmh.com/ARPA/NAVYSAF/SYSTEMS/GUN/GWS_SD.html) April 1996

30. "FFG-7 OLIVER HAZARD PERRY-class" (http://www.globalsecurity.org/military/systems/ship/ffg-7.htm) October 2002

31. "3-inch 76 MM" (http://www.otomelara.it/products/spec.asp?pid=2) October 2002

32. "Phalanx Close-In Weapons System" (www.raytheon.com) October 2002

33. "Weapons" http://users.visi.net/~markmcb/NewFiles/Weapons%20Pages/Weapons.html October 2002

34. "MK 15 Phalanx Close-In Weapons System (CIWS)"

(http://www.fas.org/man/dod-101/sys/ship/weaps/mk-15.htm) November 2002

35. Statement of Rear Admiral Phillip Balisle, US Navy Director, Surface Warfare Division before the Seapower Subcommittee of the Senate Armed Services Committee on surface warfare systems, 9 April 2002

36. "Ships Self Defense Force/ Weapons Admin & Security," (http://www.fas.org/man/dod-101/navy/docs/swos/ops/73-13.html) October 2002

37. "Overseas Picture Album" (http://zbh.com/oseas/oseas.htm) October 2002

38. Federation of American Scientists "United States Land Warfare Systems" (http://www.fas.org/man/dod-101/sys/land/index.html) October 2002

39. Javelin Field Manual (DRAFT), October, 2002 (http://www.infantry.army.mil/29thInf/courses/javelin/FM3-22.37/index.htm)

40. E-mail interview between P. Carey, Lieutenant Colonel, USA, Javelin Program Office and the author, 15 November 2002

41. Raytheon, "Phalanx Block 1B CIWS" (slides) (http://www.dtic.mil/ndia/ammo/martin.pdf) October 2002

42. Naval Vessel Register, (http://www.nvr.navy.mil/index.htm), 23 November 2002

43. Buck, C.S., *A Case of the Dual Sourcing Strategy as Used in the Acquisition of the Army's Javelin Medium Anti-Armor Weapon Program*. Master's Thesis. Naval Postgraduate School, Monterey, California, December 1995

44. Telephone interview between M. Shamblen, Anti-Armor Weapon Specialist (on the Division Staff),Guns and Munition Division, Naval Surface Warfare Center, Dahlgren and the author, 23 November 2002

45. Telephone and e-mail interviews between M. Dixon, Acting Javelin Engineering Team Lead, Javelin Program Office, and the author, 20-25 November 2002

46. Telephone interviews between S. Kerry, Former Javelin Contracting Officer and the author, 25 November 2002

47. Chairman of the Joint Chief of Staff Instruction, CJCSI 3170.01B, 15 April 2001

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